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ABSTRACT

This report is an attempt to develop a comprehensive picture of the biomedical equipment technician (BMET), who spends at least 50 percent of his time repairing and maintaining biomedical equipment. In order to alert potential employers to the technician's capabilities, and to provide information on establishing training programs, the report identifies the characteristics of the technology, the types of BMET's in the field, the institutions which employ them, and the training which BMET's currently receive. On the basis of data gathered during 278 interviews with employers of BMET's in 25 major cities, it was predicted that the demand for BMET's will double by 1975. The report recommends that all BMET training programs emphasize skills in electronics, troubleshooting, and repair, with secondary emphasis on mechanics, electro-mechanics, communications skills, and administrative-management skills. The program should focus on specialties which are found through interaction with potential BMET employers to be relevant to the regional job market. (Author/BH)

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TERC Technical Education Research Center

INTERIM REPORT II

Survey of Job Characteristics.

Manpower Needs and Training Resources.

as of June, 1970.

Development of Career Opportunities for Biomedical Equipment Technicians

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TERC Headquarters:
44A Brattle Street
Cambridge, Mass. 02138

TERC Offices in:
Los Angeles, California · Milwaukee, Wisconsin · Springfield, Massachusetts
Stillwater, Oklahoma · Urbana, Illinois · Waco, Texas · Washington, D.C.

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INTERIM REPORT II

Survey of Job Characteristics, Manpower Needs and Training Resources, as of June, 1970.

DEVELOPMENT OF CAREER OPPORTUNITIES FOR BIOMEDICAL EQUIPMENT TECHNICIANS

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ABSTRACT

This report is an attempt to develop a comprehensive picture of the biomedical equipment technician (BMET), a technician, who, by our definition, spends at least fifty percent of his time repairing and maintaining biomedical equipment. The goal of this report is twofold: 1) to alert potential employers to this technician's capabilities; and 2) to provide potential educators with information helpful to establishing and continuing BMET training programs in response to employers' needs. We hoped to achieve these goals by identifying the characteristics of this technology, the types of BMET's in the field, the institutions which employ them, and the training which BMET's presently receive. The data used as the basis of this report were gathered during 278 interviews with employers of BMET's in twenty-five major cities across the country.

We found a number of different types of BMET's employed in the different institutions which are integral parts of the health care delivery system: hospitals, research institutes, medical equipment manufacturers, medical equipment contract maintenance companies, and medical supply houses. The two outstanding types of technician are a generalized technician, most often found in hospitals, who works on a wide range of medical equipment and components; and a specialized technician, most often found in companies, who is also highly skilled but works on only a few types of medical equipment.

The need for BMET's will almost double by 1975. Many hospitals are now realizing the advantages of employing competent in-house technicians to maintain the ever-growing amount of medical equipment they are acquiring. Industry, where the majority of BMET's are now employed, will continue to hire BMET's in proportion to companies' growth in sales.

Regardless of the form, length, and location of a BMET training program, it was found that such a program should emphasize skills in electronics, troubleshooting, and repair, with secondary emphasis on mechanics, electro-mechanics, communication skills, and administrative-management skills. The program should focus on whatever specialities are found relevant to a local or regional job market. Such relevance can only be achieved through interaction with the potential BMET employers concerned.

ACKNOWLEDGMENT

This survey could not have been completed without the time and ideas of many people. We would like to express out appreciation to those men and women in hospitals, schools, and companies across the country who gave their time and interest to our interviewers. The names of these institutions are listed in Appendix P. Special thanks goes to our "experts", listed in Appendix S, whose thoughtful critiques of this report served as guidelines for its completion. We are grateful to these and to countless others in hospitals, companies, professional associations, colleges, and universities who assisted in every aspect of this survey. It is their interest and concern in the biomedical equipment field that gives this report its purpose.

PREFACE

This research report describes the results of a nationwide survey conducted in the spring of 1970 to determine the current job characteristics, manpower needs, and the training resources and requirements for biomedical equipment technicians (BMET's). The survey was carried out as part of TERC's continuing effort to keep abreast of changing needs in the field and their implications for training programs. An earlier survey was reported in 1967 under the title, Development and Evaluation of Educational Programs in Bio-Medical Equipment Technology, Phase I; the survey reported here employed somewhat more refined techniques, sought more information, and covered a broader geographical area.

As in other emerging occupations, performance and safety standards have not yet evolved; and the rate and direction of development are difficult to define with precision. Few people can speak with certainty concerning the future of the technology and its application to national health care. Accordingly, we have given the report a style and format different from the normal research document, but more appropriate, we feel, to the lack of precision inevitable in the field at this time. Our picture of the BMET and his career options has been assembled from impressionistic, anecdotal data, from the opinions of well-informed people, and from the statistical or "hard data" collected in the survey. We hope this style will make the report more readable and useful to those with peripheral interests, as well as to those intimately concerned with the employment and training of BMET's.

TERC is interested in receiving comments on the usefulness and quality of its work. Critiques of the first draft of this report were solicited from a number of persons knowledgeable in the biomedical equipment field, and are included in Appendix D. We will welcome other criticism which any reader may have of the report; only through such "feedback" can we learn how we may better serve the interests of young people choosing careers in this field, of the organizations that train them, and of the public and private institutions that employ them.

TERC is a non-profit public service organization devoted to the improvement of occupational and technical education throughout the United States. The research reported herein was performed pursuant to grant number OEG-0-8-000975-1873(513) from the United States Office of Education, Department of Health, Education and Welfare. Centers undertaking such projects under Government sponsorship are encouraged to express

freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

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INTRODUCTION

The many problems of our country's health care system are well documented in numerous articles, books, speeches, and legislation. Some of the most pressing problems are the lack of trained personnel, rising hospital costs, and the inaccessibility of good health care services to well over one-third of the population. At the same time modern technology is contributing an enormous quantity of new equipment and devices in the field of biomedical instrumentation.[1]

It would appear that these technological developments, skillfully applied, could do much to resolve health care problems. But such application has not occured--partly because the medical field is traditionally slow to change, and partly because there are not enough allied health professionals knowledgeable in either the safe, effective application or the maintenance of the new equipment.

Recently, new professions that relate to the applications of biomedical equipment have begun to appear. A segment of the health profession population--some doctors, engineers, and administrators--is gradually becoming aware of the solution which this new breed of technical professionals can provide to the cumbersome problem of utilizing new instrumentation in medical research and, more importantly, in direct patient care. These solutions must be defined and then shared with the rest of the health industry, including the educators of health technologists.

Our particular interest and concern is with one specific emerging occupation - the biomedical equipment technician (BMET). This technician might well provide a solution to hospitals' problems of how to repair and maintain their ever increasing amount of sophisticated medical equipment, how to make decisions about which equipment to purchase, and how to ensure the equipment's safe and effective use. The purpose of this study is to identify this technician in terms of how he (or she) is presently functioning in hospitals and medical equipment companies, and then to share this information with potential employers and

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1. The medical electronics market is projected to increase two and one half times in the next five years--realizing approximately 1.5 billion dollars by 1975--as reported by DMS, Inc. in a January 1970 study.

educators. We hope that this report will help some of these employers discover ways to utilize this new professional to a greater extent and that some educators will be able to develop training programs which will be appropriate to the needs of the BMET. Perhaps most importantly, we hope that both employers and educators will find that these objectives are best achieved through interaction and cooperation with each other.

METHODOLOGY

This report is based on a nation-wide survey of institutions which employ biomedical equipment technicians. The global objective of this study was to identify the existing and potential need for the BMET and the problems of this emerging occupation, as well as to locate resources that can satisfy, or be mobilized to satisfy, these needs and problems. The specific objectives of the survey were:

(a) to identify the ways hospitals organize the repair and maintenance of their medical equipment;

(b) to identify the institutions (hospitals, medical research foundations, manufacturers of medical equipment, medical supply houses, medical contract maintenance companies) and the departments in those institutions in which the BMET is employed;

(c) to determine the different types of technicians existing in the field;

(d) to determine the kinds of tasks performed by a BMET, and the kinds of equipment on which he works;

(e) to determine the status of this occupation as reflected by the career potential, and the ways in which this technician interacts with and is viewed by hospital staff;

(f) to determine the educational and career backgrounds of BMET's, where they were trained before they came on the job, how they are trained on the job, and what employers look for in prospective BMET's;

(g) to determine the manpower growth rates in the field, what constraints have been put on these rates in the past, and what will affact them in the future.

On the basis of these objectives, two questionnaires were developed for use in the survey. The first questionnaire was designed on the basis of recommendations from hospital administrators in the Boston area and members of the TERC staff. It was mailed to hospital administrators in all hospitals in major

cities across the country. It sought information on how hospitals organize the repair and maintenance of their medical equipment and how much importance they place on this issue. (For a summary report on over 240 responses to that questionnaire, see Appendix E.)

We combined the successful aspects of the questionnaire format used in previous TERC studies, and the comments and suggestions by individuals in the Boston area familiar with the biomedical equipment technician in developing the second questionnaire. It was used to gather a variety of information from a variety of different types of BMET employers through a personal interview. (See Appendix A for a critique of the questionnaire.)

A team of ten interviewers was given a five-day training session prior to their two-to-three weeks of interviewing in twenty-five major cities across the country.[1] The session served to familiarize them with the biomedical equipment field and with interviewing techniques. They were instructed in how to use the questionnaire as a research tool, how to select respondents for the sample, what kind of information to seek which was not directly asked for on the questionnaire (including pertinent information on existing BMET training programs), and how to code the questionnaire once an interview was completed.[2] (See Appendix B for a critique of the training week.)

Each interviewer was provided with a list of potential contacts including: pages from the American Hospital Association Guide listing the hospitals in the one or two cities and surrounding suburbs in which she (he) would be interviewing, and a list of manufacturers, supply houses, and contract maintenance companies which several hospitals in each city had mentioned as

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1. We chose to interview in major urban areas for two reasons: a) it is more likely that larger hospitals employ BMET's and larger hospitals are more often found in urban areas, and b) more companies employing BMET's are likely to be found in larger urban areas. By eliminating rural areas from our sample we do not intend to imply that we are ignoring their needs; it is quite likely that rural hospitals have much greater needs for the BMET's repair service than urban hospitals who have a variety of repair resources available to them.

2. Standard coding procedures were used. For each question a code was developed based on the range of responses. Numerical values were assigned to each code, answers were coded, they were transferred to code sheets, and punched on computer cards, creating a data deck.

providing repair service. We had no idea what percentage of these contacts actually employed BMET's. Interviewers were instructed to try to schedule ten to twelve interviews a week, with approximately 60% of them in hospitals and 40% in companies. The vast majority of BMET's are no doubt employed in companies; but because we felt (a) we knew less about the hospital BMET, and (b) the growth in employment of BMET's would more likely be in hospitals than in companies, and (c) fewer training programs are available for the hospital employed BMET, we decided to focus our survey on hospitals even though this might not give us a representative view of the field.

Interviewers were instructed to locate respondents once they arrived in a city by first ascertaining by telephone if the institution in question had anyone in its employ whose primary responsibility was the repair and maintenance of medical equipment, and if so, who the supervisor of that employee was. We felt it was best to conduct the interview with supervisors of BMET's since they would have an overview of the whole department; nevertheless BMET's themselves could be, and in many cases were, quite productively interviewed.

When calling a hospital, an interviewer generally asked for the engineering, maintenance, or purchasing office to seek information about whether or not they employed a BMET. When calling a company, they generally asked for the service or repair department. It was not unusual for an interviewer to speak with three or four individuals in a given institution before locating a person who could say with certainty whether or not they had a BMET in their employ. Once the interviewer located BMET supervisors or BMET's themselves, she introduced the potential respondent to the goals of TERC and the aims of the study, and determined whether or not he would be willing to participate in our survey by being interviewed for an hour or so. If the contact was interested in the survey but had no time during the week the interviewer was in his city, he was mailed a copy of the questionnaire to complete on his own. Very few contacts who had BMET's refused to participate at all in our survey. Table 1 shows the breakdown of contacts.

TABLE 1

BREAKDOWN OF CONTACTS FOR BMET SURVEY

	Hospitals/ Research Institutes[1]	Manu-facturers	Supply Houses	Contract Main-tenance	TOTAL
#personally interviewed	173[2]	30	50	12	265
# interviewed by mail	6	5	2	0	13
# who failed to return mailed questionnaire	7	15	12	11	45
#w/BMET's who refused to be interviewed	4	30			34
# contacted w/no BMET's	150	18			168

1. Because of the small number of research institutes interviewed (6) and their close association with hospitals, for the purposes of this report research institutes and hospitals are grouped together.

2. The vast majority of hospitals (105) ranged in bed size from 200-700 with a mean size of 300-400 beds.

Table 2 shows the breakdown of interviews completed by city, Table 3, the type of respondent, and Table 4 the department in which the BMET is employed.

TABLE 2

NUMBER OF INTERVIEWS COMPLETED PER CITY

CITY			
Atlanta	9	Miami	10
Baltimore	7	Milwaukee	11
Boston	10	Minn/St. Paul	15
Chicago	9	New Jersey	8
Cleveland	11	New Orleans	12
Dallas	9	New York	9
Denver	15	Philadelphia	10
Detroit	12	Pittsburgh	11
Houston	13	San Diego	1
Indianapolis	8	St. Louis	15
Kansas City	12	San Francisco	23
Los Angeles	17	Seattle	12
		Washington D.C.	10
			278

TABLE 3

TYPES OF RESPONDENTS INTERVIEWED

RESPONDENT	
BMET	80
Company supervisor (inc. service and sales managers, department heads)	85
Hospital supervisors (inc. dept. heads, assistant administrators, MD's)	39
Engineers	73
	278

TABLE 4

PERCENTAGE OF BMET'S EMPLOYED BY VARIOUS DEPARTMENTS IN HOSPITALS AND COMPANIES

Hospitals:	Laboratory (clinical or research)	7%
	X-ray/Nuclear Medical	4%
	ICU/CCU	2%
	Inhalation Therapy	9%
	Engineering	22%
	Maintenance	19%
	Central Supply	1%
	Biomedical Engineering	24%
	OTHER	14%
		100%
Companies:	Sales	6%
	Service	56%
	Clinical (Lab, X-ray)	6%
	BMET	8%
	Not applicable (company too small)	18%
	Don't know	6%
		100%

After three weeks of interviewing, the interviewers returned to Cambridge for a two-day debriefing session. At this time interviewers' general impressions on a number of different issues were elicited and recorded. The interviewers went through the questionnaire as a group, to ascertain which (if any) questions were explained to or interpreted by respondents in a variety of ways, or which proved to be troublesome, thus creating doubtful validity in the data. The interviewers also went through the coding process they used on each question to insure consistency in the coding, and codes were developed for many of the open-ended questions. The coded data, once checked for a variety of errors, was punched on to data cards and fed into the computer for various statistical analyses.

This report is based on both the soft data (quotes from respondents, impressions of interviewers) and the hard data (frequencies of responses to specific questions). By using a combination of these two kinds of data, we felt that we would be able to achieve a high degree of reliability and validity. As a final check, we have asked over thirty people involved with

biomedical equipment technicians to review and critique our report, commenting on its objectivity and representativeness of the field. Some of their comments appear in Appendix D.

THE ORGANIZATION OF BIOMEDICAL EQUIPMENT MAINTENANCE

Hospitals arrange for the repair and maintenance of their medical equipment in a variety of ways constituting a series of interactions among hospitals, medical research institutes, manufacturers and suppliers of medical equipment, and medical equipment contract maintenance companies. Personnel in these institutions, because of their participation in this network, have definite and often different views on who is most qualified to handle the servicing of medical equipment, and thus where the repair responsibility is likely to lie in the future. Interviewers were able to pick up a variety of these perspectives during the survey.

All hospitals have at least a part of the repair and maintenance work on their medical equipment done by manufacturers or suppliers. Most equipment comes with a minimum six-month warranty (a fair percentage has a one-year warranty) covering service and repair. On many kinds of medical equipment, repair of certain sealed components can only be done by the manufacturer or supplier who has the proper tools, schematics (circuit diagrams, blueprints), and spare parts. In no hospital did the respondents state that repair and service could or should be carried out exclusively by in-house technicians.

The general sentiment was, however, that an increasing amount of medical equipment maintenance and repair is being handled by an in-house hospital staff. This was indicated by the projected doubling of BMET manpower in hospitals by 1975. This growth will be dependent upon a continued awareness on the part of hospital administrators of the cost/benefits of employing BMET's, continued growth in the amount of medical equipment purchased (especially patient rather than research oriented items), as well as a loosening of the constraints put on hospitals by manufacturers or suppliers who do not provide schematics, circuit diagrams, spare parts, or specialized tools.[1]

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1. One respondent suggested that manufacturers tend to shy away from providing manuals, schematics, spare parts and repair tools because of the legal hazards involved in unskilled hospital repair people attempting to repair complex products without sufficient training or background.

"Mr. T. (a BMET supervisor) feels that once the hospital looses its shortsightedness, BMET's will have a good future. There aren't presently, however, any good training programs for the caliber of men the hospital hopes to hire." (interviewer's observation)

"Hospital administrators haven't realized how much money they could save by having their own BMET's - one local administrator was in an ICU as a patient a few weeks ago - some of the equipment broke down. You should see him scream now for a BMET. . . Another hospital saved almost $100,000 last year because they hired a BMET." (respondent's comment)

"The problem in educating hospitals to the need for in-house technicians is a public relations problem -- to make them see that the cost of outside contracts is so great that minimal in-house maintenance on the equipment is an absolute necessity." (respondent's comment)

"The respondent was a BMET who had to sell himself to the hospital. By use of cost analysis over a one-year period, he convinced the administration that they could operate much more effectively and economically through an in-house staff." (interviewer's observation)

"There are many pieces of equipment that these men <u>can</u> fix, but don't because of the contract. There are others that they could fix but don't because they haven't any way of getting the parts for repair. If these constraints were removed, we could develop a workable, centralized system of repair." (respondent's comment)

"We've started to use BMET's because they're less costly - we don't have to buy back-up gear, we get speedier service - especially in coronary care and in the OR. It's convenient. Also, people who use the equipment know the BMET's and trust them." (respondent's comment)

"This hospital would definitely like to establish its own system of repair and maintenance of medical equipment. However, they have the following restrictions to contend with: lack of schematics, wiring diagrams to work with - manufacturers won't provide these with the installation of equipment; the hospital won't let the BMET's touch items under contract or warranty; hospitals sometimes cannot and sometimes will not buy necessary parts or instruments essential for troubleshooting." (interviewer's comment)

"T. feels it would be wise economically for the hospital to use in-house technicians, and knows that many department heads agree, but thinks that it would be quite difficult to convince the hospital administration since gaps in communication exist between the department heads and the administration." (interviewer's observation)

Although the majority of hospital-employed respondents seemed to feel that hospitals were, wisely, moving in the direction of employing their own staff of BMET's, there were some skeptical respondents, some of whom were employed in hospitals, and many more in companies.

"Having an in-house BMET would be far more costly than a contract with the manufacturer -- after all, the manufacturer is going to continue to control the sale of spare parts, chemicals, etc." (respondent's comment)

"This hospital has no BMET's. They have a few electrically-oriented maintenance men who do very minor repairs on some medical equipment, but spend most of their time on other electrical equipment. They have no interest in developing a BMET staff. They think it would be a waste of money. They are happy relying on contracts and warranties." (interviewer's observation)

"Hospitals are just starting to realize the need for repairs by contracts. They're beginning to understand that, as medical equipment becomes more sophisticated, they can't handle the repairs themselves. They need our help." (contract maintenance company respondent)

"The purchasing manager insisted that an in-house BMET isn't practical because equipment is becoming more and more complex and only the manufacturer can handle major repairs." (interviewer's observation)

"The hospital could go in one of two directions: (1) contract maintenance companies with me as in-house coordinator or (2) full-scale BMET staff. I'm recommending the former -- I just don't think that we can afford a full-scale BMET staff." (hospital BMET's comment)

Clearly larger hospitals are in a much better position to use BMET's, but several medium-sized hospitals were among the most enthusiastic BMET employers. We believe that hospitals under 150 beds are probably best off depending on service contracts or sharing a pool of BMET's with other small hospitals. We did encounter one situation in which two small hospitals used the services of a BMET from a third hospital. This sharing

process, although not widely used now, is certainly beneficial to small hospitals from the point of view of economy and efficiency.

All respondents recognized the need for manufacturers to employ BMET's and agreed that their BMET manpower growth would likely parallel their growth rate in sales. Manufacturers, as well as suppliers, understand that they must continue to supply hospitals with repair service. It is unlikely that they would ever want to eliminate their service departments entirely as service accounts for 10% of their annual gross income, according to the Arthur D. Little, April 1969 study.[1] Manufacturers have mixed emotions about hospitals employing their own BMET's. Some worry that in-house BMET's can only cause additional trouble by clumsy repair which the manufacturer must then rectify. Others are thankful to be relieved of the necessity of service calls for minor repairs which the in-house technicians can handle.

Contract maintenance companies appear to be relatively new sources for equipment service. In actuality, very few (twelve) were found in our survey and those that were found were generally only three to five years old.[2] While their services are certainly marketable, according to some manufacturers such companies do not employ the most skilled technicians and do not take the issue of safety in application of equipment seriously. However, these feelings may be more a reflection of competition between the two types of companies than a reflection of the actual skill level of contract maintenance company BMET's. Hospital respondents were concerned about the high cost of using contract maintenance companies and about their inability to effect all repairs, thus necessitating a call to the manufacturer anyway. While some who interact within the medical equipment repair system may be opposed to the expansion of contract maintenance services, these

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1. See Arthur D. Little Study in Bibliography, Appendix Q. Despite this, at least one respondent pointed out that in some instances service calls do not produce a profit for the company as the entire service charge may go to the serviceman. In such cases, according to one respondent, companies consider service to be a headache.

2. As far as we know, there are no professional organizations involving contract maintenance companies. They appear to have no set performance standards to follow

companies will doubtlessly continue to grow and to employ more of the available BMET's, especially if manufacturers provide these companies with the necessary schematics and tools.[1]

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1. From this point on in this report, BMET's employed by manufacturers, suppliers and contract maintenance companies will be referred to as "company BMET's." While there may be differences between these three types of companies, we cannot make any meaningful statements about them because of the relatively small number of cases of each in our sample.

WHO IS THE BMET?

It is impossible to describe the "typical" BMET because, as is often the case in a developing occupation, there is no prototype, no stereotype, and certainly no consensus among educators, employers, and technicians themselves as to what a BMET can and should be. Our technicians have come from fields ranging from carpentry and fumigation to electronics and mechanics. It is easier to generalize about the BMET's employed by medical equipment manufacturers than about BMET's employed in hospitals, where we encountered the most variety of types; but all BMET's were sufficiently different to make every interview interesting and enlightening. Before describing the BMET statistically and generally, perhaps we can give our readers some feeling for the variety of BMET's by describing a sampling of the people whom we interviewed.

> Charlie, a timid white-haired man in his late 50's, is a janitor, or more precisely, an electrician. He has a high school education and has been at his hospital for almost 20 years, falling lately into some minor repairs on some of the common medical instruments because he is readily available in the building. To the doctors he is a non-professional, seen around with a ladder changing light bulbs, on the tractor mowing the lawn, and occasionally tinkering with respirators, incubators, and centrifuges. Charlie talks only when spoken to; he is well liked rather than well respected, but everyone recognizes that he is indispensible to the smooth running of the hospital. He was really quite touched that he was being interviewed--perhaps no one had taken an interest in his work in all those twenty years.

John works in the psychiatric research lab of a medical school. He too is in his fifties, and has worked himself up through the ranks to the impressive title of Superintendent of Research Instrumentation. Like Charlie, he is a "dirty fingernails" technician; but John is a specialist--an electronics whiz who lovingly designs and builds computer units. He is proud of these as he is of his daughter who goes to a fancy private school. Unlike Charlie, he is a colorful character, known throughout the school for his talking as well as his electronic ability. However, he will never move any higher because he has no degree, and he jealously defends the importance of a man's job skills over his "ability to learn French or Latin." He compares himself to Tom Edison: "He didn't even graduate from high school--who'd give him a job today?"

Jim is in his 20's, and recently finished his military service duty, where he received most of his electronics and BME training. Although he is full of energy and ideas, he had to persuade the hospital administrator to hire him by convincing the administrator of his value and worth. His youthful appearance is deceiving of his technical and professional competence. He is articulate about his role as a BMET; about the need for knowledge of the physiological aspects of the instruments; and about the need for skill and tact in communicating with hard-headed professional people. He had hoped to organize an effective preventive maintenance system and to arrange seminars on the safe use of equipment for nurses and lab technicians, but there has been no cooperation and no time to do so. Jim is a victim of hospital ignorance; he is under-utilized, under-paid, and under-equipped with the necessary tools and work space. He will probably leave soon and look for work with a company.

Bob is one of the few black BMET's in our sample. Young, good-looking and well-dressed, Bob is an activist. Like John, he works in a Research Unit. He is involved not only in the professionalism of his job, but also in developing BMET and other allied health training programs for disadvantaged blacks. Intellectually astute, politically aware, he is influential both as a member of the Afro-American group at the university and as a professional in the BME field. He received his background training in the military.

Jack went from the stock yards to a career in the service as a BMET. He even spent some time teaching at Fitzsimons in the Army BMET program before retiring and going to work for a contract maintenance company. He is a robust, beer-bellied technician, more aware of his field than he appears at first. Jack is vigorously pro-Army, claiming that only they know how to train BMET's. He recognizes the low status of his job compared with that of the graduate engineer and sees certification as the tool to gain proper recognition. "Isn't there some cat up in Boston who's trying to get us certified?" he asked.

The above character sketches are not intended to be representative of all BMET's in our sample, but only to suggest the spectrum of personalities and backgrounds. While we emphasize that we cannot identify a "typical" technician, we did find that it was possible to group the BMET's into three general types; a description of these technician types follows.

TYPES OF BMET'S

While the "technician" who works on repair and maintenance of medical equipment is easily identified in both company and hospital settings, he does not necessarily fall into a single working definition of the "real" BMET.[1] As in other emerging technologies, there are no standard procedures for entering the field of biomedical equipment repair; there is no certification, no universally acknowledged job requirements. In our survey, however, we were able to define three different technician types based on the kinds of medical equipment the technician works on and the subsequent skill levels required of him. The three types, described in greater detail in Part I of this chapter, are as follows:

TABLE 5

TYPES AND NUMBERS OF BMET'S FOUND IN OUR SURVEY[2]

	Hospitals	Companies
THE JANITORIAL TECHNICIAN:[3] A member of a hospital maintenance department who repairs some of the less sophisticated medical equipment when called on, but not really as part of his job.	34	0
THE GENERALIZED TECHNICIAN: A technician employed either in a company or hospital who is responsible for a wide range of medical equipment.	83	22
THE SPECIALIZED TECHNICIAN: A technician employed in a company or hospital who is responsible for a small number of types of medical equipment, usually reflective of the equipment found in one particular hospital department.	62	76

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1. By our definition: a technician who spends at least 50% of his time on the repair, maintenance, or modification of sophisticated kinds of medical equipment.

2. Interviewers classified respondents on the basis of the number and types of biomedical equipment the technicians worked on.

3. There is an obvious conflict in the juxtaposition of the words janitorial and technician, but after due consideration, we felt this was the most realistic title.

Among the generalized and specialized technicians, it is possible to identify at least four types of technicians based on their functions and the kind of institution or department in which they are employed. These four types, discussed in greater detail in Part II of this chapter, are as follows:[1]

THE ADMINISTRATIVE TECHNICIAN: A medical equipment repair technician found in hospitals and companies whose primary functions include cost analysis, communication, and organization.

THE FIELD SERVICE TECHNICIAN: A medical equipment repair technician found in companies whose primary responsibility is installing and servicing equipment in his area, but who might also sell his company's equipment.

THE PROFESSIONAL TECHNICIAN: A medical equipment repair technician found in companies and hospitals whose primary responsibilities include the modification and design of medical equipment.

THE OPERATOR/REPAIR TECHNICIAN: A technician whose primary responsibility is operating medical equipment in a particular hospital department, but who is also responsible for the repair and maintenance of the equipment he operates.

For the purposes of this report, it was found most useful to classify respondents according to the janitorial, generalized, and specialized types. The administrative, field service, professional, and operator/repair types are described here to indicate the range of responsibilities which a BMET may assume.

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1. The numbers of each of these four types in our sample were not determined.

PART I: CATEGORIES OF TECHNICIANS BASED ON THE RANGE OF EQUIPMENT THEY WORK ON

"Janitorial" Type[1]

This technician has had little, if any, preparation for handling medical equipment except for rudimentary electronic and mechanical skills he has picked up on the job. Accordingly, his work is limited to the apparatus commonly found in hospitals such as stills, sterilizers, EKG's, and incubators. He spends much of his time repairing non-medical equipment. Few people in the hospital regard him as a "repairer" of medical equipment; doctors are apprehensive about what he might do to their equipment and the resulting effect on their patients.

It is often this man who bears the brunt of all the stereotyped images which doctors and nurses have of the "mechanic" or "electrician" who fiddles with their equipment and "does not really know what he's doing." He rarely interacts professionally with medical or paramedical personnel. They do not see him as a professional technician, and they do not want him to tell them how to use equipment or what kind of equipment to buy.

The janitorial type sees himself more as a maintenance man than as a BMET, and is generally found in the maintenance department wearing a janitor's uniform. His career ladder allows him, with some schooling, job experience, and seniority, to move up to the position of a stationary engineer.[2]

> "He has his own office off the boiler room in the basement The office is clearly 'makeshift' -- crowded, inadequate working space and repair area, inadequate tools. One shelf contains a few manufacturers' manuals. Clearly visible are two TV sets which might have recently been brought in for repair. He wears the electrician's armor on a belt around his waist (including flashlight, screwdrivers, hammers, wrench, etc.) and a green janitor's costume, although he claims to be a BMET." (interviewer's observation.)

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1. This title, used by one of the respondents, is again employed purely for descriptive purposes.

2. A stationary engineer in a hospital is responsible for machinery such as boilers, generators, motors, and power sources.

"The electricians in this hospital repair some medical equipment, but never the life support systems. The administration is holding back a bit because of fear of having BMET's repair things incorrectly, resulting in patient death. They'd rather have the manufacturer be responsible." (respondent's comment)

"The BMET's here are janitorial types - it seems to be a function of the fact that the hospital has a limited budget in the medical equipment area. They pay very little and get semi-retired men mostly with experience as electricians." (interviewers's observation.)

"A typical day: AM - repair centrifuge in a lab, then fix a leaking pipe upstairs. Replace a light fixture. PM - adjust a heart monitor, work on laundry equipment, end up on dietary equipment or a dishwasher. In a day he might walk all over the hospital, but only on the basis of work requests!" (respondent's comment.)

"Generalized BMET-Type"

This type of technician works on a wide range of medical equipment, cutting across department lines, and covering most of the items on the equipment list in the questionnaire. He spends a large proportion of his time on major and minor repair, with some emphasis on scheduled preventive maintenance. In a hospital he might be found in a bio-engineering department, but more often he comes under the supervision of the hospital engineering/maintenance department. He might also be found in companies which provide repair services for a wide range of medical equipment. Many of these generalized BMET's have extensive electronics training and/or have had some biomedical equipment training in the military. The rest generally have a straight electronics background, - any required "medical" skills are picked up on the job, with some help from short courses offered by manufacturers.

These men rarely admit that there are any repairs beyond their capabilities. The extent to which they are supervised varies, and they see themselves as distinct from janitors and regular maintenance men. This technician does not like to work on non-medical equipment except as a source of extra income. Their image of themselves as important to the functioning of the hospital is reflected in their dress (sometimes white coats, sometimes sports clothes with a tie, sometimes they carry a paging beeper), and the extent and variety of ways in which they interact with the medical staff (they see nurses and doctors daily, sometimes advising them on how to operate equipment and what kinds of equipment to buy.) In addition,

their higher status is indicated by well-equipped offices away from the boiler room with a lot of work space. However, the generalized BMET's frequently feel that hospital personnel, especially doctors and administrators, do not grant them the respect they deserve.

The careers open to him are varied depending upon the size of the institution in which he works. The larger institutions (hospitals with over 300 beds and large manufacturers and supply houses) generally have more room for upward mobility, allowing the BMET to move into supervisory or engineering positions on the basis of ability and experience. Smaller hospitals and companies are less able to offer BMET's positions of increased responsibility; instead, they offer increases in salary.

> "The department which supervises the technicians has been newly renovated - includes a waiting room, lounge area and about ten offices - it's lighted and spacious." (interviewer's observation)

> "The BMET's office is in the basement, yet it's clean and spacious. One room contains shelves and shelves of manufacturers' manuals, circuit diagrams, schematics, textbooks on electronics, mechanics, optics, and medicine, and various engineering journals. The second room has lots of bench space, all varieties of test equipment, and a bulletin board with a neatly arranged work schedule for the week including sections for priority work orders, other work orders, and preventive maintenance." (interviewer's observation)

> "Our technicians are very sensitive to being classed with maintenance and repair men, so we call them all field engineers." (respondent's comment)

> "The most important function of the BMET? - advising administrators and department heads on what equipment to buy , what the spec's should be, etc. Administrative ability in addition to top-notch electronics and technical knowledge is essential." (respondent's comment)

> "MD's and other purchasers of medical equipment should confer with us before buying things. Salesmen can sell you anything and we could help MD's make better decisions." (respondent's comment)

"Any technician entering this field can't look at it as a 40-hour a week job. It can be 24 hours a day including weekends." (respondent's comment)

"Both technicians made a point of indicating that they felt they didn't have a whole lot of responsibility and prestige. They did feel they were really a lot better off than technicians in private hospitals where there is even less status and prestige associated with the BMET." (interviewer's observation)

"Mr. Z's men don't like to work in hospitals because of the bad treatment they get from medical staff. MD's very often do not respect the ability of the BMET and the BMET who is highly skilled doesn't like to put up with that kind of treatment." (interviewer's observation)

"In a work week one generalized BMET's schedule included work on the following items of equipment: Mon. - closed circuit TV, paging system central service equipment, ICU; Tues. - all day on one piece of X-ray equipment; Wed. - dental drill, monitors, blood-gas analyzer; Thurs - oxygen analyzer, portable X-ray, TV; Fri. - cauterizer, preventive maintenance on some OR equipment, mass spectrometer." (interviewer's observation)

"Specialized BMET-Type"

This type of technician is generally employed by a company or hospital department that is involved with a small number of instruments. He works at a fairly high level of competency, spending a large proportion of his time on major repair and preventive maintenance. His background includes strong electronics and sometimes military medical equipment training. It is not clear from our observations whether or not he could work on a wider range of medical equipment if he had to. He is frequently asked to perform functions other than repair, such as modification and design, operation of the equipment and/or sales.

Because he is specialized, his skill level may be higher than that of the more generalized BMET--at least in general he is granted more status. The careers open to him seem to be of a wider range and perhaps more appealing. He can move in the direction of design, modification, and building of equipment or, in the case of the specialized technician employed at a company, in the direction of sales or supervision. When employed in a hospital he is generally in a specialized medical

department such as ICU, inhalation therapy, or X-ray. However, he is sometimes found in the engineering/maintenance departments of hospitals which have either just started to repair their own medical equipment and are concentrating on a small number of pieces of equipment at first, or have such a large staff of BMET's that they can afford to have specialized technicians.

When employed by a company, he is generally specialized by the kind of equipment the company is manufacturing, selling, or servicing. Large companies with many BMET's usually have additional specialization by components, by individual pieces of equipment, or by different lines of equipment. Many respondents feel that this specialized BMET might well be the forerunner of what most BMET's will be like in the near future, especially if the biomedical equipment field continues to expand rapidly. In their opinion, the growing diversity and complexity of medical instrumentation will make it impossible for one man to work on all types of medical equipment, and the BMET will by necessity be specialized.

> "A typical day: Spend morning on the phone with people from anywhere across the country diagnosing the problems they're having so that they can repair them - that's the way lots of repair work is done, over the phone. In the afternoon he might take some part orders, service our equipment in a couple of hospitals or do bench work on equipment that was brought in." (respondent's comment)

> "His technicians are highly skilled and obviously well-utilized, and much appreciated -- almost too sophisticated to be called BMET's. They spend most of their time modifying equipment and they even build some of it from scratch." (interviewer's observation)

> "The respondent is a cardiopulmonary lab technologist - he does not favor the BMET concept. He would prefer to have paramedicals gain enough familiarity with their equipment to service it because they understand what it's used for. However, he does feel that the more complicated electronic equipment should be handled by specialized technicians." (interviewer's observation)

> "The field is just becoming too specialized - hospitals will have to hire whole departments of specialists to work on all the types of medical equipment they'll have." (respondent's comment)

"These people are developing a different type of BMET - a combination BMET and surgical technician. Not only can he repair machines in an emergency, but he is also there to assist in the operation. This gives the technician, among other things, a greater feeling of importance." (interviewer's observation)

"Today equipment repair is becoming more and more specialized. It would be impossible to become knowledgeable in more than one area in a short length of time. It would take years of on-the-job training with a prerequisite of basic electronics and mechanics to function effectively in <u>one area</u>." (respondent's comment)

PART II: SOME SUB-TYPES OF TECHNICIANS BASED ON THE TASKS THEY PERFORM

As mentioned on page 18, other classifications can be used to describe BMET's on the basis of their functions within hospitals and companies.

"Administrative Technician"

This technician is skilled in cost analysis, organization, and communication. His primary functions are managerial, including coordinating the preventive maintenance program, organizing and scheduling the repair of medical equipment (much of which is done outside the hospital), advising on the purchasing/leasing of equipment, determining the most economical method of repair, and sometimes instructing hospital staff in the safe, efficient use of equipment. While he is capable of doing repairs, this is not his most important function. Our sample included very few of these technicians, but they could be quite useful in smaller hospitals located in cities which have many sources of maintenance available. In this position of "clearinghouse agent" for hospital repairs, the BMET needs the skills necessary to interact constantly with hospital staff and company representatives.

> "To characterize my job -- clearinghouse and routing things to the proper repair facility. We needed someone in the hospital who understands repair and can deal with manufacturers and contract maintenance companies because purchasing and engineering don't know about it." (respondent's comment)

> "All equipment bought is under a guarantee for the first year - therefore the technicians don't work on that equipment - but they are responsible for making sure the contract maintenance company or manufacturer comes in to fix it." (respondent's comment)

> "The philosophy of our department is that if personnel are taught the safe, efficient use of all types of equipment, breakage will be significantly reduced. We have met with great success. Most minor repairs are done by our staff...what little they can't do, we send out to the company involved. This "luxury" of company service is, at present, affordable, because our failure rate has dropped to about one-half, as has expense for repair." (respondent's comment)

"Field Service Technician"

This type of technician is not employed by hospitals but is a representative of a manufacturing or supply company. Although a field service technician's primary responsibility is not the sale of equipment, his work is sales related and he must display the company image at all times. He usually performs the very important function of new equipment installation. His job then involves keeping his company's equipment in working order and thus keeping the customer happy. His territory can be large, and to avoid unnecessary travel and expense to the customer and the company, he often handles minor repairs over the phone by discussing the problem with the equipment operator or an in-house service man. He must visit the hospital for major repairs, any scheduled preventive maintenance, and calibration. A field service technician usually has the respect of most hospital personnel because he has established himself as an expert on his specific equipment.

Employers of such a technician claim that a pleasant personality, a certain "savoir faire" in dealing with doctors, and a neat appearance are almost as important as a knowledge of electronics, mechanics, and medical equipment. In fact, some companies gave the impression that they would rather hire a pleasant person and teach him electronics than hire an electronics expert and teach him to be pleasant. While salaries are high for this type of technician, they are higher for a straight salesman, and thus the position of salesman is often his next step up the ladder.

> "The only reason we provide repair service is to keep our customers. The most important thing about this repair service is not how well or fast the repair is done, but how nice the repairmen are." (respondent's comment)

> "I have to deal with doctors and nurses and often tell them things they can't easily take -- like they've been operating the equipment wrong. So what I do when say an EKG is reported broken is go to the hospital, pretend to fix it; if I know that the only problem is the way the nurse has been hooking it up to the patient, then I tell the nurse that as part of my job I'm supposed to give a lecture on how to use the equipment. I tell her that I know she probably knows how to work it, but would she mind listening just so I can do my job. She listens all right, and carefully, because she knows deep down inside that she was doing something wrong. See, I'm playing a game with the nurses, but I have to - it is part of my job!" (respondent's comment)

"Most of the administrators in the branch offices have come up through sales and service. The BMET can move up to sales after 8 years and then on to management." (respondent's comment)

"The men are primarily salesmen, not repairmen. They only act as repairmen because they have to, otherwise hospitals wouldn't buy their equipment. Respondents would be happy if hospitals had their own men to do at least minor repairs." (interviewer's observation)

"Professional Technician"

The professional technician is more likely to be found in hospitals than in companies. He usually has his own shop and is highly skilled, taking a great deal of pride in a job which he finds both interesting and satisfying. The professional technician might handle the whole range of medical equipment, or just one or two speciality areas. One source of challenge in his work is the modification he is often asked to do. Particularly in larger teaching/research hospitals, doctors frequently develop ways to connect or revise different systems of medical equipment, requiring the BMET to use his creative design and modification skills. In many cases he is not someone working for doctors, but is a co-worker with doctors. This type of BMET is interested in accreditation, and he would most likely be involved with teaching hospital employees the safest and most effective ways of operating equipment

"This technician works directly for the physicist and an MD. He shares their research lab and in many phases of the work is their equal. When he's not repairing the equipment he's operating or modifying it. Sometimes he's called by other departments in the hospital complex to repair equipment, but his bosses prefer him to remain in their research department. If he's conscientious sSs enough, if he's interested enough, some day he could move from repair technician to research assistant." (interviewer's observation)

"A person in my position has got to be quick to learn, has got to be up on the field, has got to put his entire time into this. I've got to keep abreast of the field - there is often a gap between what the working electronics technician is and what the knowledgeable electronics technician should be." (respondent's comment)

"The BMET spends much of his time giving planned seminars to the entire nursing staff. He feels it's important for everyone to be familiar with the equipment to minimize breakdown - the greatest percent of equipment failure can be attributed to lack of operating knowledge on the part of the staff." (interviewer's observation)

"These two men really felt their job was a challenging one, requiring skill, perseverance - they looked upon their job as a real profession - they were involved with constant reading and study to keep up with the field." (interviewer's observation)

"When we want to insult our man, we call him our "service engineer." Usually, he is referred to as a research associate." (respondent's comment)

"Operator/Repair Technician"

This technician spends most of his time operating the equipment in a particular hospital department, but he is also responsible for its repair and maintenance. He might work in inhalation therapy, X-ray, nuclear medicine, or in one of the laboratories, usually under the supervision of a doctor. He was probably first an equipment operator and learned the repair techniques on the job. Because he has more contact with patients than any of the other types of BMET's, it is of primary importance that he have "a good bedside manner". He often wears a white lab coat and shares the status of most paramedicals. The careers open to him include not only the various paramedical technician positions in a hospital, but also positions in the sales or services departments in a company.

"Tony probably has a different kind of status from the ordinary repairman, because the medical people in the hospital know that he talks their language." (interviewer's observation)

"We prefer to have him spend all of his time operating our lab equipment, but of course if something breaks down he has to fix it. People in other departments are always calling to see if he'll fix their equipment - we don't like him to do that too often." (respondent's comment)

"This BMET operates the heart-lung machine during an operation. He has to know how to repair it because if it breaks down during the operation, the patient could die." (interviewer's observation)

"This doctor felt that the BMET who both operates and repairs equipment is the only kind that should exist and that with the increased purchase of medical equipment in hospitals, this technician's role will be critical." (interviewer's observation)

COMPARATIVE ANALYSIS OF JANITORIAL, GENERALIZED AND SPECIALIZED BMET'S

As was stated earlier, for the purposes of this study it was found most useful to classify and analyze respondents according to the first three BMET types: janitorial, generalized, and specialized. We now compare these types on the basis of background, functions, salary, and tasks.

All of the janitorial types were found in hospitals, the majority of them general hospitals;[1] 80% of the generalized and 42% of the specialized BMET's were also found in hospitals, fairly evenly distributed among teaching, research, and general hospitals. Most of the generalized technicians employed by companies were found in medical supply houses; most of the specialized technicians were employed by manufacturers.

Background

In looking at the education and job experience backgrounds of these three types of technicians, the janitorial type remains distinct. As seen in Table 6, significantly larger percentages of the generalized and specialized BMET's have had some post-secondary schooling, including training at a technical institute or other two-year school, at a four-year college, or in a military training program. Furthermore, Table 7 shows that while the greatest percentage of each technician type has come from an electronics background, a smaller percentage of the janitorial type has had this background. Additionally, he is more likely than either the generalized or specialized BMET to have had a mechanical background. Thirty-one percent of the janitorial types come from backgrounds other than the relevant technical areas, a percentage significantly larger than for the other two types. This "OTHER" category includes occupations

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1. It is very likely that a large percentage of all hospitals have a man in their maintenance department who does at least some minor repair on a few pieces of medical equipment. The few men of this type whom we interviewed by no means represent the number of these technicians who exist in the field. In general, if such a man was contacted by an interviewer, no interview was arranged when it became evident that he was not spending at least 50% of his time repairing medical equipment. It could be argued that at least some of the thirty-seven janitorial types interviewed should not have been included in our sample, yet their presence does help give us a representative picture of how repair of medical equipment is presently handled.

ranging from working in the post office to carpentry.

TABLE 6

EDUCATIONAL BACKGROUNDS OF BMET TYPES IN OUR SAMPLE

	% Technician Types		
	Janitorial	Generalized	Specialized
% not high school graduates	12%	5%	3%
% high school graduates	56	26	23
% post-high school training[1]	32	69	74
	100%	100%	100%

TABLE 7

AREA IN WHICH BMET TYPES WERE WORKING BEFORE HIRED

	% Technician Types[2]		
	Janitorial	Generalized	Specialized
% biomedical equipment	6%	32%	15%
% electronics	31	44	53
% mechanics	28	9	5
% optics	0	1	1
% electro-optics	0	1	1
% electro-mechanics	4	3	2
% OTHER	31	11	25

1. A few of the technicians in this catetory are college graduates (generally with majors in physics, chemistry or life sciences); some are graduates of one of the two military training programs, and well over one-fourth are graduates of some technical institute. Many of the others have taken courses at a two or four-year college or university. At least one technician had a Master's degree (in psychology).

2. Do not add up to 100% as trace figures were rounded to nearest full percent.

The employer of the generalized BMET placed more emphasis on military background than did employers of the other two types: of those technicians in our sample trained in the military, almost half of them are now generalized BMET's.[1] The military is known to provide excellent training in both electronics and biomedical technology (see training chapters). Employers of these military-trained generalized technicians apparently are pleased with their performance and would like to hire more of them.

TABLE 8

PERCENTAGE OF TIME SPENT ON FUNCTIONS BY BMET TYPES

Functions	Janitorial	Generalized	Specialized
Administrative	2%	7%	9%
Operating Equipment	2%	3%	4%
Preventive Maintenance/Calibration	17%	18%	18%
Repairs/Troubleshooting	20%	47%	41%
Modifying/Designing/Building	4%	8%	11%
In Training/(upgrading)	5%	5%	5%
General Hospital Maintenance (non-medical equipment)	41%	7%	3%
Instructing Others	4%	5%	7%
OTHER	19%	0%	2%
	100%	100%	100%

1. The great majority of these men were trained in basic electronics, television and communications, and so on, rather than in medical equipment repair. Military trained men make up 23% of the BMET's in companies and 22% in hospitals.

TABLE 9

PERCENTAGE OF TIME SPEND ON EQUIPMENT COMPONENTS BY BMET TYPES

Components	Janitorial	Generalized	Specialized
Electronics	22%	53%	53%
Optics	1%	3%	3%
Mechanics	40%	14%	17%
Hydraulics	4%	3%	3%
Electro-mechanics	14%	17%	16%
Electro-optics	1%	4%	3%
Pneumatics	5%	3%	4%
OTHER	13%	3%	1%
	100%	100%	100%

The janitorial type is functionally distinguished from the two other types of technicians: a larger percentage of his time is spent working on non-medical apparatus, and a smaller percentage is spent on repairing and troubleshooting medical equipment. He spends much less time on electronics and much more time on mechanics than do the other two types.

Generalized and specialized technicians are not easily distinguishable from each other on the basis of percentage of time spent on various functions and equipment components. However, by looking at the kinds of equipment they work on, differences become evident. As can be seen by higher percentages in Table 10, many more generalized technicians work on more items of equipment on the list than do specialized technicians. The low percentages for most of the items under specialized technicians indicate that each specialized BMET works on very few kinds of medical equipment. More of these technicians (approximately 40%) were specialized by ICU/CCU equipment than by any other equipment group. Close to 20% were specialized by X-ray/nuclear medicine equipment, 10% by laboratory equipment, and the remainder were divided among inhalation therapy and operating room equipment, anesthesia apparatus, and computers.[1]

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1. This breakdown of specialized types probably reflects in part the types of companies we chose to interview rather than the distribution of specialized technicians in the field in general.

TABLE 10

PERCENTAGE OF EACH BMET TYPE WHO REPAIRS SPECIFIC BIOMEDICAL EQUIPMENT

Type of Equipment	% Performing Repairs		
	Janitorial	Generalized	Specialized
blood-gas analyzer	30%	71%	35%
autoanalyzer	24	59	21
blood cell counter	21	57	27
refrigerated centrifuge	59	59	23
spectrophotometer	21	73	34
flamephotometer	30	64	28
stills	64	59	16
gas-chromatographs	8	45	26
mass spectrometers	5	34	9
pH meter (or titrator)	21	71	34
balance: precision (mechanical)	18	46	20
balance: electronic	10	47	20
microtomes	13	50	20
microscopes	43	59	19
cardiac monitor	59	90	63
pacemaker (external)	49	76	52
EKG	69	96	65
defibrillator	59	89	2
alarm system	72	87	55
respirator (ex. Bird)	40	5	27
electrosurgical cauterizer	73	86	23
anesthesia apparatus	35	45	16
surgical pumps	63	73	23
heart-lung machine	13	1	15
X-ray equipment	33	42	23
scintillation counter	16	43	24
radiation monitors	21	47	19
scanner	21	42	18
prosthetic devices	5	22	1
analog/digital computers	5	32	1
refrigerators	73	30	8
dental equipment	33	39	10
air conditioners	73	17	3
sterilizers	81	66	16
dialysis systems	18	43	10
incubator: infant	69	60	19
	N = 37	N = 103	N = 138

Salary

Another parameter differentiating the three types of technicians is salary - the salary a technician might expect before he completes his training, the salary he can expect once training is for all practical purposes completed, and the maximum salary he might expect at the highest BMET level in his institution. As can be seen in Table 11, all three technician types can expect the same salary while in training. The janitorial type is paid less once his training is completed, and he can expect a lower maximum salary. The specialized technician can expect the highest maximum salary.[1]

TABLE 11

AVERAGE SALARY LEVELS FOR BMET TYPES

	Janitorial	Generalized	Specialized
Salary while in training	$6-7,000	$6-7,000	$6-7,000
Salary after training completed	$7-8,000	$8-9,000	$8-9,000
Maximum salary	$9-10,000	$10-11,000	$11-12,000

Starting, average, and maximum salaries for all technician types ranged from under $4,000 a year to over $16,000.[2] For the BMET in training, the average salary was $6-7,000, with no appreciable difference between salaries offered by hospitals and companies. Once the technician completes training, he can expect an increase in salary to approximately $8-9,000 per year, whether he works in a hospital or company. The BMET can look forward to a maximum salary of approximately $10-11,000 year year if he works for a company or $9-10,000 for a hospital.

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1. Salary figures reflect 1970 standards.

2. Many respondents were unwilling to answer these questions, and some were unable to answer them. Others answered with difficulty as their institution either had no set salary scale or no concept of "average" salary, or salaries varied depending upon company profits or union bargaining. Thus while data may give an indication of the range of possible salaries, they should not be taken as absolutely representative of salaries in the biomedical equipment field.

Tasks

Finally we can look at the technician types in relation to the specific tasks they perform as part of their more general functions of troubleshooting, repair, calibration, and maintenance of equipment. Although this information was collected on the basis of frequency a given task was performed by the technician, for the purposes of this report it becomes more meaningful to discuss simply whether or not each technician performs the task. Table 12 is the list of those tasks presented in order of the percent of respondents who performed them. These percentages are given by institution (hospital or company) as well as by technician types. Note that over half of the tasks (1-12) are performed by at least 70% of the respondents.[1]

There are differences in time spent on each task by the three technician types. It appears that the janitorial BMET is more closely supervised than the specialized and generalized BMET's since he keeps more routine records of his daily activities, and he less often plans his daily schedule, determines the order in which repairs should be accomplished, or estimates how long a given repair will take or how much it will cost. He is also less involved with the clerical aspects of the job, such as ordering supplies or maintaining files. His lower professional status is additionally illustrated by the fact that he is called infrequently to troubleshoot equipment while it is being used on a patient, and he spends a good deal of his time repairing non-medical equipment. Because he is generally involved in the electrical system of the hospital, however, he would naturally check on safe installation of equipment.

There are only a few tasks where there are differences of even slight significance between generalized and specialized BMET's. Because generalized BMET's are more likely to be employed in hospitals, it is understandable that they are more involved in repairing non-medical equipment and in maintaining files of manuals for the variety of equipment in the hospital. This might also explain why they more frequently transport equipment to a repair shop: specialized technicians who are already working in one department would consider that their shop. Specialized BMET's are more involved in selling because they are frequently company employees.

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[1] While this indicates that most of the tasks that we selected for this list are relevant to BMET's it does not mean that this list is by any means conclusive. Tasks such as report writing and keeping up with relevant journals may not be integral parts of the technician's job.

TABLE 12

PERCENTAGE OF BMET'S PERFORMING TASKS (BY INSTITUTION AND TYPE)[1]

	# Res.	% Respondents Performing Task: Total	Hos.	Co.	TECH. TYPE[2]: J	G	S
1. Work with blueprints or wiring diagrams	255	95	95	97	95	99	92
2. Transport faulty equipment to repair shop	255	88	88	81	89	91	79
3. Determine order in which repairs should be accomplished	254	80	78	83	64	85	83
4. Be on call for emergency service during non-working hours	255	79	76	85	88	81	79
5. Estimate for someone else how long a repair on a given item will take	255	77	74	83	69	80	78
6. In troubleshooting equipment at its normal location, be able to determine whether it is correctly hooked up to the patient	252	77	75	81	47	85	80
7. Order supplies, spare parts from manufacturers, supply houses, etc.	255	76	78	73	53	82	78
8. Plan and schedule his own assignments for the day	255	75	78	72	61	75	80
9. Maintain files of manufacturers' manuals/circuit files, etc.	255	75	78	71	67	87	77
10. Maintain a log of his daily activities	255	74	72	79	80	71	75
11. Maintain an inventory of spare parts	255	71	73	68	61	75	71
12. Make rounds of hospital to check on safe installation of equipment	255	71	73	68	80	69	70
13. Estimate cost of repair for a given item of equipment	255	62	58	70	44	71	60
14. Coordinate and schedule preventive maintenance program for medical equipment	254	52	55	47	45	55	52
15. Bill other departments for his services	254	38	32	48	31	42	37
16. Repair non-medical equipment such as elevators, air conditioners, etc.	255	38	52	11	84	44	20
17. Interview and help select prospective BMET's	255	37	39	32	36	40	35
18. Selling equipment or service/ "hand-holding"	98	35	13	81	25	31	47
19. Plan and schedule assignments for other technicians	252	31	31	28	28	28	34

1. Differences less than 10% were considered not significant.
2. J = Janitorial, G = Generalized, S = Specialized.

The few significant differences between companies and hospitals are also expected. Companies are more involved in cost and time estimates and in billing because of the profit factor; and non-medical equipment is repaired in hospitals because it is part of the functioning of the institution.

A DAY IN THE LIFE OF A BMET

Having gathered statistical information on the BMET, we felt that it would be useful to follow a BMET through a "typical" day. A member of the TERC staff spent a few days at a large general Boston hospital observing Dave, a generalized BMET. This is an account of one of his work days.

When Dave arrived at 8:00 a.m., he changed into his maintenance work clothes and then checked to see if any emergency work orders had come in. One of the nursing units had requested a repair on a defibrillator lead, so he selected the necessary tools from his work bench and went to the unit. The repair was a simple one, requiring soldering a broken cable. Next, he stopped in one of the chemistry labs and picked up an autoanalyzer pump which needed repair; the terminal board was shorting. Back at his work bench, he fixed the pump and also gave it the regular preventive maintenance check, including cleaning and oiling it. As he marked the preventive maintenance check in his log book, he explained that, since instituting regularly scheduled preventive maintenance on most of the medical equipment a year ago, he had to spend much less time on major repairs.

Next, he calibrated, checked, and cleaned a radiation meter, which he left running to make sure that the measurement did not fluctuate. On returning the autoanalyzer pump to the lab, he was stopped by a lab technician who explained that she had taken the flamephotometer apart and noticed that the brass column was cracked. Dave replied that, since the flamephotometer was old, it might be more economical to purchase a new brass column. He promised to check the column and determine whether it was better to purchase a new part or to have the machinist weld the cracked one.

After he picked up two other autoanalyzer pumps for preventive maintenance, he and several other maintenance men went to have coffee with the engineer. He and the engineer discussed a cost analysis that the engineer had done to persuade the hospital administration of the economic value of hiring an in-house BMET. Even when figuring in the cost of purchasing the

necessary test equipment and a stock of spare parts, the hospital has saved a considerable amount of money by hiring a BMET.

After the coffee break, Dave went back to the labs to talk over a problem with the operator of the large, automated chemical analyzer - SMA 12/60. Its flamephotometer ignitor had burned out. Dave made arrangements to do the repair late in the afternoon when the lab technician had completed running her tests. While he was there, another technician reported that the washing machine for the glass equipment used in the lab tests had broken. Although the machinist would usually handle this since it was a mechanical problem, Dave volunteered to repair it because he knew that the machinist was busy.

At this point, his beeper sounded, and he had to postpone the repair of the washer because of a broken monitor in the Coronary Care Unit. After picking up the necessary repair tools from his work room, he went to the CCU and discussed the problem with the supervisor. Then he located the source of the trouble in the recorder, repaired it, and cleaned and oiled it. The CCU supervisor watched while he repaired the recorder, and Dave explained what he was doing. While there, his beeper sounded again: it was a pathologist from a neighboring hospital whom Dave had been instructing in the basics of maintenance and repair of lab equipment and in the fundamentals of electricity and electronics. The pathologist plans to teach his residents so that they can make better decisions about purchasing and repairing instruments.

Dave then returned to the work room to do preventive maintenance on the autoanalyzer pumps. He was interrupted to respond to a call from the Special Care Unit. The stylus on a monitor needed adjustment, and since the monitor was attached to a patient, he hoped to repair it on site. Once there, however, he determined that a new stylus component was needed, so he and the head nurse removed the monitor from the patient. Dave wheeled it back to his workshop, determined the number of the part needed, and called the manufacturer to order a new part. He then gave the specifics to the secretary, who sent in a formal purchase order. By this time, it was noon.

Most of the maintenance department staff gathered for lunch and "shop talk" in Dave's work room. The engineer mentioned that the lab was going to purchase another spectrophotometer, and asked Dave if he had any recommendations about which to buy. After checking his log book, Dave suggested a particular brand that had caused little trouble, and the engineer agreed to mention it to the purchasing committee.

During lunch, the head of the lab stock room called Dave and told him that three EKG machines needed adjustment. Upon arriving in the EKG department, Dave chatted with the chief EKG technician, who was annoyed because the interns had thrown two of the styluses on the machines out of calibration when using them at night. Dave agreed with her that operator-misuse was the primary factor in equipment breakdown, but noted that this was less of a problem now, since he had spent a lot of time over his three years at the hospital instructing key people in each department (usually the supervisor) in how to care for the equipment and how to recognize maintenance problems at their onset. After adjusting the styluses on two EKG's and adjusting (or tightening) the cabinet on the third EKG, Dave returned to repair the washing machine in the lab, joking with the operator of the machine about its generally dilapidated condition.

About 2:00 p.m., Dave returned to his workshop to do preventive maintenance on the autoanalyzer pumps, and found that the Special Care Unit had delivered a bedlamp to him to be fixed. Ordinarily, this type of repair would have been routed to the electricians, but the SCU usually sends most of their repair work to Dave, and he does it.

As he was logging in the preventive maintenance check on the autoanalyzer pumps, one of the lab technicians called him, explaining that the chart paper was not rolling out of the SMA 12/60 and she could not finish running her tests. Just as he arrived in the lab, however, his beeper sounded; some hosing on the deep therapy X-Ray machine had suddenly sprung a leak. So he ran over to the X-Ray Department, took the back off of the X-Ray tube, and located the split hose. He then called the engineer to ask if he should attempt to improvise, since he didn't have the right kind of tubing or clamp, or if he should call in the manufacturer, who was supposed to have replaced the tubing several weeks before. The engineer called the local division of the manufacturer, and after learning that they had no spare hoses in stock, he and Dave "improvised" and successfully repaired the hose connection - getting soaked in the process.

Dave then returned to the lab, checked out the SMA 12/60, and determined that the amplifier tubes in the recorder needed to be replaced. He also changed the ignitor, soldering the connection.

Finally, he returned to his work bench and, testing out the lamp, diagnosed the problem as a faulty plug, which he replaced. He took the extra precaution of tinning the copper wires with

solder before fiting them into the plug. While he was recording all of the repairs he had done into his log book, three more requests for repair came, and he scheduled them for the next day. The head nurse in the Cardio-Pulmonary Surgery Unit asked Dave to check the leads on one of their defibrillators, and also asked if Dave would repair her transistor radio on his own time. An inhalation therapist called and described a problem in the electrical connection in a hypothermia blanket. Lastly, the supervisor of the Operating Room called and said that their electronic marker was broken. Dave explained that he did not know what an electronic marker was, but he would take a look at it anyway.

It was nearing 4:30 p.m. Having organized his work bench and jotted down some reminders to himself, he changed back into his street clothes and went home.

JOB QUALIFICATIONS

> "The field contains an enormous variety of types; from jolly and outspoken to withdrawn and serious; from self-satisfied to discontented; from highly competent to tinkerers; from high school students to graduate engineers. It seems that someone is filling each of the job qualifications mentioned by respondents and it may well be, as one man said, 'you usually get an oddball'." (interviewer's observation)

We discussed with each of the respondents what he expected of a man he hired to fill a BMET position. Typical of the comments are the following.

> "We look for strong technical capabilities, especially a good electronics background. An AA degree or an equivalent from the military is desirable. Medical equipment changes so much, it would be nice if he knew physiology and chemistry, but we don't require it." (respondent's comment)

> "Lots of public relations is involved in the job, therefore the technician must have a certain savoir faire - it's hard to tell a MD he's done something wrong. Proficiency with electronics is no more important than the way one handles people. Grooming, appearance, command of English, self-discipline are all important to good customer contact." (respondent's comment)

> "Stating the job qualifications is hard - I never had seen half of this equipment before I came here - I learned about the equipment from schematics. I would probably expect a basic electronics background with heavy emphasis on troubleshooting procedures." (respondent's comment)

> "I strongly prefer a man with experience with X-ray equipment and formal electronics training, but I'd hire someone with minimal background if he's seriously interested in the field and seems reliable and stable and appears to communicate well. In this job, you have to be tactful and effective with doctors and other hospital personnel." (respondent's comment)

Not typical of the comments, but interesting nonetheless, are the following:

"He must be breathing."

"No women! The work is too heavy for a women and women just don't get enough respect in a hospital."

"Hé can't be color blind as many machines require color differentiation. He also must have good eyesight."

"He must have a clear police record."

"He must be older - and married. Then we have some guarantee he'll stick around for a while."

"He should possess loyalty, courage and a sense of fairness."

Comments were coded in order to determine which qualifications were most frequently mentioned. As can be seen in Table 13, an electronics background is the single most important variable in determining eligibility for a BMET position. Mechanics and other subject areas such as physiology and chemistry were not mentioned nearly as frequently.

TABLE 13

STATED JOB QUALIFICATIONS BY INSTITUTION AND BMET TYPE

% of Respondents who Mentioned

	Total	Hosp	Co.'s	J	G	S
Electronics	77%	74%	83%	49%	84%	81%
Mechanics	37	37	36	47	40	31
Other subjects (including physiology, chemistry)	24	26	21	22	27	23
Good appearance	14	1	24	13	11	16
Nice personality	34	31	41	31	35	35
Communication skills, savoire-faire	23	15	39	11	17	31
Initiative, aggressiveness	21	20	24	8	21	25
Schooling						
high school grad.	13	14	12	16	14	11
2 yrs, post high school	27	25	30	11	30	30
4 yrs. college	2	2	6	0	2	2
Schooling not important	10	8	11	19	9	7
Job experience important	35	38	19	37	39	30
Military experience important	7	8	5	0	15	6

Among the various personal characteristics mentioned by respondents, a pleasant personality seems to be the most important; but communication skills and "a certain savoir faire" were mentioned often. The technician comes into contact with all members of the hospital staff, and must interact smoothly with this variety of people.

Forty-two percent of the respondents commented on the importance of education. Among these, the majority felt that two years of schooling beyond high school was important. Over 30% of the respondents mentioned that former job experience was important.

Employers of the three types of BMET have different job qualifications for the position in their institution. Electronics background, intiative or aggressiveness, and post secondary schooling are not as important to the employer of the janitorial type as to employers of generalized and specialized technicians. While the differences in job requirements between employers of these two types are few, they are interesting. The generalized BMET's employer is more likely to emphasize former job experience--perhaps because more of these employers are hospitals which are neither committed nor equipped to intensively train BMET's. The employer of the specialized technician is more apt to emphasize communication skills and ability to get along with others, as most of the specialized technicians are employed by companies and thus are responsible for representing their company's image when they service customer's equipment.

In summary, employers of BMET's are looking for a man with a strong electronics background; knowledge of medical equipment, a good personality, communication skills, and some schooling after high school are appreciated but knowledge of electronics far outweighs them in importance.

CAREER

The career lines for the BMET can be determined by both the possibilities for upward mobility and the salary potentials in a particular institution. Our data allow us to make some comments on career possibilities for the BMET.

Approximately half of the institutions in our sample (51%) stated that they have a number of grades or levels of technicians based on parameters other than salary. These grades were based on skill level and the types of tasks the technician performs, as well as supervisory responsibilities. Examples of career levels within various institutions are as follows:

(LARGE MEDICAL CENTER)

1. ELECTRONICS TECHNICIAN: capable of all minor and some major repair.
2. SENIOR TECHNICIAN: capable of all minor and major repair and calibration.
3. PRINCIPAL TECHNICIAN: capable of all repairs and calibration although his primary function is supervisory.
4. JUNIOR ENGINEER: capable of all repairs and calibration plus design and modification. Labeled an engineer on the basis of ability and experience, not on schooling.

(MANUFACTURER)

1. TECHNICIAN: performs minor bench repairs
2. SENIOR TECHNICIAN: performs major bench repairs
3. FIELD ENGINEER: makes calls on hospitals to perform repair work.
4. SENIOR FIELD ENGINEER: makes calls on hospitals to perform installations and repairs, as well as to instruct hospital staff in the use of equipment and how to effect preventive maintenance.

(MILITARY)

1. MEDICAL EQUIPMENT REPAIRMAN (MER): works on all biomedical equipment excluding X-ray and nuclear medicine, but under close supervision.
2. ADVANCED MER-GENERAL: works on all biomedical equipment excluding X-ray and nuclear medicine, without supervision.
3. ADVANCED MER-RADIATION: Works on all X-ray and nuclear medicine equipment without supervision.

Of those institutions with different levels of BMET's, 37% stated that they had only two technician levels, and 35% stated that they had three. The remaining institutions had from four to as many as nine levels. While the average number of levels was three, hospitals tended to have fewer BMET levels than did companies (2.8 compared to 3.5). Table 14 summarizes the replies of respondents to the question, "How does a technician move fron one grade of technician to another?"

TABLE 14

HOW BMET'S IN SAMPLE MOVE FROM ONE GRADE TO ANOTHER

28%: by seniority

36%: by going to school

82%: by displayed ability

48%: based on experience

13%: OTHER (such as performance ratings, promotional opportunities in the organization)

It appears that the single most important factor in determining upward mobility for a technician is the display of technical ability on the job. Respondents indicated that on the average it takes one to two years to progress from one level of technician to another. In institutions with only two or three grades, a competent technician could rise from entry level to the highest grade of technician within four to six years. After that he can only anticipate additional raises in salary, unless he is determined to move up to engineer status.[1]

The ways of moving up to engineer status, in Table 15, are different from those for moving up the technician ladder:

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1. While "engineer status" was intended to be interpreted as professional status, respondents may have interpreted it in a variety of ways including positions such as stationary engineer, field engineer, degreed engineer, etc.

TABLE 15

HOW BMET'S IN SAMPLE MOVE UP TO ENGINEER STATUS

12%: by seniority

73%: by going to school

56%: by displayed ability

40%: based on experience

While demonstrated ability on the job is significant, going to school is the most important factor in determining mobility from technician to engineer status. A higher percentage of companies (49%) than hospitals (39%) stated that such a move is possible. On the average, respondents seemed to feel that it would take a technician at least 5 years (and in many cases, 10 years) to complete the necessary requirements (i.e., experience and schooling) to move from technician to engineer.

Regardless of the number of levels of BMET's, or the ways in which the BMET moves from one level to another, companies generally seem to have more clearly defined, predictable, career lines for the BMET. This is possibly because companies have been employing BMET's for a longer time than hospitals.

HOW BMET'S ARE TRAINED

In general, BMET's in hospitals and most companies are trained informally on-the-job by other BMET's, engineers, and, though rarely, doctors. It is clear that companies rely more heavily on structured training than do hospitals. Approximately 30% of the companies interviewed indicated that they have a formal, in-house, on-going program of training; only about 10% of the hospitals had such a program. We should note, however, that formal training programs range from simply structured, well-supervised on-the-job training to those that include lectures and labs and use textbooks, video-tapes, and instructional modules.

We found one university (Northeastern University in Boston) and six community colleges or technical institutes with formal two-year associate degree BMET programs, two military BMET programs (Army and Air Force), and one community college whose program has been discontinued, primarily due to lack of funding.[1] The training offered by these institutions differs considerably. Military programs do not include basic course requirements such as English, psychology, and physical education; all of their courses are specifically oriented to medical equipment repair. Military courses are also shorter and considerably more intensive. Their teaching staff are trained in biomedical equipment repair, whereas in community colleges faculty from other departments frequently teach courses in electronics, mathematics, life sciences, etc. Furthermore, military programs have many more instructors (thirty-eight in the Army program compared to one to three in a community college) and many more students (approximately 135 students per year in the Army program compared to sixteen in the largest community college program.)[2] Entry requirements differ too. Military programs have multiple entry points determined by previous training and advanced placement testing. They do not emphasize that the student be a

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1. Detailed descriptions of these programs are included in Appendix K.

2. It is interesting to note here that A. Harvey Belitsky, in his book Private Vocational Schools and Their Students: Limited Objectives, Unlimited Opportunities, uses the same criteria in comparing private and public technical institutes. (Schenkman Publishing Company, Inc., Cambridge, Mass., 1969)

high school graduate, although it appears that most of the students are.

There are also differences in content, curriculum, and the components and kinds of equipment which are emphasized. For example, the life sciences (biology, physiology, chemistry) are usually specifically related to the equipment in military programs; in community college and technical institute programs they are more often taught as general courses. Less emphasis seems to be placed on life sciences in the military programs, partially because the BMET will be working closely with medical technologists and therefore does not need as much expertise in this area. In terms of equipment and components of equipment, the military programs simply have a greater quantity and variety of equipment to use, and therefore are able to teach more components more intensively than can community colleges and technical institutes. Community colleges and technical institutes tend to focus on electronics, while military programs also teach more mechanics, optics, and so on.

Comments about the effectiveness of the formal training now available were varied. Most respondents who were graduates of military programs, or who had military-trained BMET's working for them, felt that military BMET training was excellent - in fact, the only adequate training available. A few interviewees, however, commented that military-trained BMET's are unsuccessful in civilian jobs because (1) "They aren't originally in a situation where they can use their own judgment" (have to take orders), and (2) "they're accustomed to an unlimited money supply, so they can replace some equipment instead of repairing it." Some respondents felt that the military training was neither intensive nor long enough, and graduates still required extensive on-the-job training once they accepted civilian employment as BMET's.

We have virtually no feedback on the effectiveness of the BMET training programs offered by colleges and technical institutes because our sample included only a few of these BMET's.[1] One BMET, (incidentally the only female BMET in our sample) had some interesting comments about her training at San Mateo Junior College, the discontinued program referred to earlier. She felt that her program had under-emphasized electronics, skill-training and chemistry, and had over-emphasized physiology and anatomy. Her clinical experience was adequate, but too narrow in that the students had very limited exposure to or training on lab equipment. The BMET students had taken physio-

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1. And most of these programs are relatively new.

logy and anatomy with nursing students, with the result that the BMET students had to learn much more than they needed to know in order to repair equipment. If she were designing a BMET program, she would focus on ICU-CCU and lab equipment, and would emphasize electronic theory, skill-training, and troubleshooting skills. She added, "Because my training was so specialized, I have a hard time dealing with equipment that I haven't been trained on. The biggest weakness of the program was inadequate electronics experience." Her criticisms of the San Mateo program are understandable because that program was specifically designed to attract females, and therefore included less electronics.[1]

The third type of formal BMET training now available is that offered by manufacturers of biomedical equipment to their own service technicians and, in some instances, to BMET's from hospitals, supply houses, and contract maintenance firms. Our knowledge of manufacturers' training is based on a small sample of in-depth interviews,[2] and responses made by BMET's and their supervisors who are employed by manufacturers. Manufacturers' formal programs for their own technicians differ from other BMET programs in two ways:

(1) Manufacturers' programs are more flexible, individualized and specific in that these programs rely heavily on home-study courses, video-tapes, instructional television, and manuals which relate to their particular equipment. The trainee's entry level skills are evaluated by examination, and the appropriate and necessary training is then based on his needs. Some programs include a week or two of intensive equipment training at the company's training headquarters, with the rest of the training conducted at a division office.

(2) Manufacturers do not teach general electronic or mechanical theory or skills. They expect that the trainee will have previously acquired such skills and knowledge, and give him instruction in these areas only in regards to the manufacturer's specific products. The training is designed to "fill in the gaps" rather than to fully train a general BMET. The training is thorough, but narrow in scope.[3]

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1. See Appendix K.

2. Ibid.

3. Once again, the differences between manufacturers' and other training programs is similar to the differences Belitsky describes between private and public technical institutes.

Actually, a very small percentage of medical equipment manufacturers have formal training programs. Our figure of 30% may be high since we tended to interview the largest, best-known companies in a particular city, which were easier to locate than smaller, less well-known manufacturers. Most companies, like most hospitals, rely on on-the-job training. It is likely, however, that the companies' on-the-job training is somewhat more structured, thorough, better-supervised, and supplemented by detailed instructional materials than that of most hospitals. Companies were not as likely to emphasize the importance of the potential employee's previous training or experience as were hospitals. We suspect that companies, particularly large ones, can afford to be more selective in hiring than hospitals who often do not have a clear idea of what the BMET should do or what department should supervise him, and who offer few promotional opportunities.

As mentioned earlier, many manufacturers run brief intensive courses, ranging in length from several days to several weeks, designed to instruct the BMET's from hospitals, contract maintenance companies, and supply houses (as well as their own BMET's) in the maintenance and repair of their products. These short courses seem to be particularly useful for hospitals, in that approximately 30% of our respondents in hospitals indicated that they send their BMET's to manufacturers' brief courses. However, as one respondent in a contract maintenance company explained, "My technicians are so skilled that these quickie courses would be a waste of time. They're too superficial, too basic - they would be an insult to their experience and intelligence." It is quite possible that BMET's in companies, particularly in supply houses, do not need to rely so heavily on the brief courses offered by manufacturers because they more often have access to the equipment schematics and wiring diagrams than do hospital BMET's.

Thirty-one percent of hospitals and 40% of companies have occasional planned in-house training sessions for their BMET's. These may take the form of informal one-hour department meetings held monthly, semi-formal instructional seminars given by manufacturers' representatives when installing equipment, or scheduled, regularly held workshops with specific topics to be covered by specific speakers (rare). Most in-house training sessions in hospitals seem to fall into the first category (informal, one-hour monthly meetings).

Although we found that most of the present training for the BMET's in our sample is on-the-job training, it may vary greatly in form, content, and length. Relying heavily on informal training presents a particular problem in hospitals because unless there is a specific Biomedical Engineering De-

partment, or at least an experienced electronics engineer on the hospital staff, the BMET must pick up skills haphazardly, from some combination of manufacturers and their instructional manuals, the medical staff, and regular maintenance men. In other cases, the hospital BMET's supervisor is responsible for his training, and training tends to be squeezed in between or during repairs. An additional problem in relying on on-the-job training in some companies and hospitals is that the training is only as good as the "instructor"; there are often no clear instructional objectives, no performance standards for evaluating the BMET's skills and his subsequent training.

Community colleges and technical institutes account for a very small proportion of the trained BMET's at present, although the number of formal Associate degree programs is expected to increase. Some technicians may take night courses at local colleges or technical institutes or use correspondence courses, but usually not in medical equipment repair.

A few other types of training were encountered, such as the workshops open to all BMET's in a given metropolitan or larger geographical area that are being conducted by two Regional Medical Programs.[1] In addition, at least one vocational high school has an interesting work-study arrangement with a local hospital where the students work with the hospital's BMET's. Their goal is not so much to teach the student how to repair medical equipment as it is to introduce him to the field. Some instrument manufacturers have informal arrangements where a hospital BMET may come and work with their own service technicians, thereby learning how to repair the company's products. A few manufacturers also include in-depth instruction in the maintenance and repair of their equipment with each installation in a hospital.

It is clear, then, that there are many options for someone interested in training BMET's. Each of the types of instruction described in this chapter has advantages and disadvantages in terms of its ability to develop a competent, skilled technician. We do not feel that we are in a position to recommend one particular type of training as being the most effective, nor do we feel that there is or should be one "ideal" form, content, length, or location for BMET training. A diversity of programs, each responding to the needs and capabilities in a given area, seems most realistic.

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1. The Minnesota Heart Association, Inc. funded by the Northlands Regional Medical Programs, and the Intermountain Regional Medical Program are both conducting workshops for the Medical Electronics Technicians (BMET's) in their area. (See Appendix M for additional information.)

HOW RESPONDENTS FELT BMET'S COULD AND SHOULD BE TRAINED

As discussed in the previous chapter, a variety of satisfactory types of training programs for BMET's presently exist. Most respondents (particularly those concerned about professionalism and upgrading of BMET's) felt that a two-year program was at least a good start. However, many potential employers emphasized that even after formal training, the new BMET would require fairly extensive on-the-job training in the company or hospital, and would have to take continuous refresher courses, especially on specific pieces of equipment.

Some respondents felt that it would be impossible to train a man to repair all medical equipment in a hospital in a two-year program, particularly if the trainee had only recently graduated from high school and had no previous experience in electronics. They claimed that the field was too technical and was changing too rapidly for any program to remain effective. These respondents included:

(a) some manufacturers who worked on only a few pieces of equipment,

(b) older BMET's or supervisors with many years of experience, and

(c) contacts in hospitals without BMET's or who employed janitorial type BMET's.

There were a few who felt that, while a BMET training program was feasible, they would rather train their own technicians. Some manufacturers, for example, preferred to train the technician on their particular products during closely controlled training sessions. Some small companies want to handle their own training because, as one man explained, "Someone with little background and experience in the field has lower career expectations and is therefore more willing to stay with us in a technician capacity." A few hospitals and small companies explained that they could neither attract nor hold well-trained BMET's because they would be lured away by the opportunities offered by large companies. At one medical center the engineer stated that he would prefer someone with only an electronics background so that he could train the technician in his own way on medical equipment.

> "I hired two graduates of a BMET program and they had too many preconceived notions about medical instrumentation. Of course, I maintain that electronics is electronics, regardless of the specific piece of equipment.

The responses on specific content and design of a training program were extremely varied and it is difficult to generalize about company versus hospital opinions. The following kinds of suggestions were made:

(a) "Very general training in the first year with heavy emphasis on electronic theory, troubleshooting, and skill-training. Varied emphasis on lab work and practical experience. Then, in the second year, or second half of the second year, specialized training by groups of equipment found in different departments in a hospital (ICU-CCU, X-ray, Lab, Inhalation, Therapy, and so on.)"

(b) "What's important in training is to educate people in the concepts employed in pieces of equipment because each manufacturer's equipment is different."

(c) "Teach as much theory as possible (don't teach a piece of equipment - you can teach a chimpanzee to do a machine)."

(d) "The more kinds of equipment that can be included the better, but the most important thing to teach is troubleshooting, particularly because we often don't get schematics or maintenance instruction with new pieces of equipment."

(e) "Ohms to amps to equipment. Must include all types of equipment, with a lot of practical experience and troubleshooting. Drawings and blueprints don't give adequate training."

(f) "Need to train operator/repair technicians, because half of the repair and maintenance problems are actually improper operation of equipment."

(g) "Very little medical background needs to be taught - he can pick it up in two months on the job."

(h) "Interviewees seemed to be split on whether a BMET should have a knowledge of medical terminology, physiology, etc., and if it was important or not. Hospital interviewees usually emphasized the importance of medical background in addition to electronics/mechanics; manufacturers were more concerned with good technical training."

One interviewer summarized the opinions on training which he encountered as follows:

"Most did not want the BMET to be trained in particular pieces of equipment. This was in line with a general feeling that the technician should be able to change with the field; new equipment is constantly being developed, and the technician has to be able to repair it. For this reason emphasis was put on skills and theory rather than on specific kinds of equipment. A few people did indicate that they'd like training in one type of equipment. These interviewees were from places which already had specialized BMET's, such as manufacturers or special departments in hospitals. These BMET's still need theoretical and practical training but they need it in specialized areas. Almost everyone agreed that the learning of a particular piece of equipment should be an on-the-job experience. In fact, a few respondents mentioned that BMET's who know a specific line of equipment have to undergo almost complete retraining to learn another line."

Opinions on training also varied depending on the type of technician desired by the employer. For example, the "professional-type" BMET (mentioned earlier) requires some kind of management training, possibly including skills in communication, department administration, cost analysis, and management of resources and supplies. He might also need training in the modification, design, and construction of equipment. Almost unanimously, employers emphasized the importance of extensive training and/or experience in electronics, as many technicians spend most of their time on the electronic elements of medical equipment.

Most respondents did not mention skills in mechanics when talking about job requirements, or if they did, they talked about mechanical aptitude in conjunction with electronics training or experience. This may indicate that either employers consider skills in mechanics unimportant, or employers assume that in working on the electronics components of equipment, the BMET would necessarily accumulate adequate experience in mechanics. In fact, one respondent said that since mechanics is easier to learn than electronics, so much easier that it can be learned on-the-job, very little mechanics should be included in a training program.

Similarly, experience or training in optics was rarely mentioned as a job prerequisite, but optics is more clearly a specialized skill, as evidenced by the fact that many hospitals send out their microscopes for major or even minor repairs; we found at least one contract maintenance company with a well developed optics department. It is possible, however, that BMET's in hospitals do not repair optical equipment because they do not have the necessary repair tools rather than the necessary skills.

Pneumatics and hydraulics were never mentioned as training topics, and these components of equipment, according to respondents, account for a very small percentage of the BMET's time. It should be understood, however, that the relative importance of training and/or experience in any component of equipment is partially a function of the department in which the BMET works - or the kinds of equipment with which he works. Thus the potential importance of mechanics, optics, hydraulics, pneumatics, and even chemistry, physics, and physiology in some BMET jobs should not be overlooked.

Approximately 63% of the companies and 85% of the hospitals interviewed indicated that they would consider helping to establish a collaborative BMET program with educational institutions, other hospitals, or other companies. The companies who responded positively suggested several modes of cooperation ranging from simply supplying equipment or manuals to arranging formal internships. Company respondents ranged from sincere to opportunistic. One man explained, "I'd be happy to take students on an internship. Not only would we brainwash them on our products and get a little extra help, but we would also be in a position to pick the 'cream of the crop', so to speak, after they graduated." Companies who responded negatively explained that they could not see how such an arrangement would be beneficial to them, and they would not have adequate time or staff to supervise the training.

Hospitals most often suggested arranging some form of internship. They occasionally suggested that they might supply some of their BMET's to teach parts of the course. Some hospital respondents felt that this internship arrangement would help the educational institution in that they could use the hospital's equipment and therefore would not have to invest in as much equipment of their own. The hospitals that indicated they would not consider establishing a collaborative program explained that there was simply no interest in their institution, or that there would be inadequate staff to supervise or train the students.

We also asked respondents to rank the type of educational institutions, hospitals, and companies with which they would prefer to work in a collaborative educational program. Table 16 shows the institutions and rating in order of preference. (Of the 224 respondents, 15% indicated no preference.)

TABLE 16

RANKING OF INSTITUTIONS IN ORDER OF PREFERENCE FOR COLLABORATIVE EDUCATIONAL PROGRAM

Community College	1	(5.7)[1]
Private Technical Institute (13-14 grades)	2	(5.5)
Public Technical Institute (13-14 grades)	3	(5.0)
University or College (4 yrs.)	4	(4.3)
Other Hospitals	5	(2.9)
High School (Vocational)	6	(2.1)
Other Companies	7	(1.8)
High School (Non-vocational)	8	(1.1)
OTHER	9	(.5)

Most respondents were not enthusiastic about working with high schools because they felt that the students would be too immature to handle the responsibility of repairing medical equipment. But, as mentioned in the chapter How BMET's Are Trained, at least one hospital has a work-study arrangement with a local vocational high school.

Working with hospitals and companies in a collaborative program received a low rating, possibly because the respondents were looking for an educational institution to provide the "academic" instruction - the general theory and skill training. Respondents indicated that hospitals and companies could well supply the student with clinical experience, but were not in a position to offer general courses.

Some respondents were hesitant about collaborating with technical institutes, particularly public technical institutes, because their local institutions had a reputation for education of an inferior quality. There was also reluctance to collaborate with universities because they felt that it would be difficult to design a two-year program within the context of a four-year university. The university might not be sufficiently "technical" in its orientation and would force the student to take too many "academic", non-related courses. Furthermore, it was felt that there would be insufficient interest in these courses among

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1. The numbers in parentheses reflect the numerical rating (raw score) received. This number was obtained by giving 5 points each time a type of institution was selected by a respondent as a first choice, 4 points each time it was chosen as a second choice, etc., and then deriving the mean rating.

universities, and that the cost would be prohibitive. Other respondents felt, however, that a university would have the easiest access to resources, funds, and good instructors, and would provide the highest quality training.

Community colleges received the highest rating. As one respondent explained, "It just seems like a natural choice because it's already a two-year college and it would provide more technical training than a university and more basic, general education courses than a technical institute."

THE EQUIPMENT TECHNICIANS WORK ON

The single most important facet of our survey was an attempt to classify BMET's in terms of the types of equipment they tend to work on and the specific tasks involved. A representative list of medical equipment was developed[1] and for each item we asked our respondents:

(a) whether the technician
   1. calibrated this equipment?
   2. performed preventive maintenance on it?
   3. performed major repairs (examples of which were requested)?
   4. performed minor repairs (examples of which were requested)?

(b) and which particular skills or knowledge the BMET should have:
   1. knowledge of how to operate this equipment?
   2. ability to locate and diagnose faults, and to repair them?
   3. knowledge of the way this equipment transforms the input signal into an output signal?
   4. knowledge of the physiological and chemical principles on which the input signal is generated?

Survey results for (a) are shown in Table 17, and for (b) in Table 18. Examples of the most frequently mentioned types of major and minor repairs are as follows:

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1. This list, while not comprehensive, is at least representative of the kinds of equipment BMET's work on. It was developed in several steps. First, two experts in the field listed thirty to fifty pieces of equipment which they felt the most generalized technician should be familiar with. These two lists were then combined and presented to members of a biomedical equipment repair group at a large Boston hospital. Based on their experience with repairing medical equipment, they eliminated some items, added others, and helped us to arrange the list according to departments in which the equipment is found. Further consultation with our in-house biomedical engineer cut the list down to thirty-six items, eliminating those whose basic components were already represented. During the interviewing process, respondents were encouraged to add any items they felt we should have included, but no pieces of equipment were mentioned often enough to lead us to believe that we had made any major oversights.

MAJOR REPAIRS

1. Repair/replace electronic circuitry
2. Repair/align/replace optical components
3. Repair/replace motors
4. Replace transistors
5. Repair/replace printed circuit boards
6. Calibrate instruments
7. Replace power transformer
8. Replace X-ray tube
9. Repair/replace compressors
10. Repair/replace pumps

MINOR REPAIRS

1. Replace fuses
2. Repair transducer leads
3. Replace simple optics
4. Replace switches
5. Replace recorder stylus
6. Replace/repair line cord
7. Calibrate/clean mechanical balances
8. Replace motor brushes
9. Lubricate/clean motors
10. Replace plastic tubing

Although the percentages of BMET's who perform calibration and preventive maintenance are slightly lower than the percentages of BMET's who carry out major and minor repairs, the difference is too small to be significant. This suggests that BMET educational programs should be designed to give the students skills and knowledge relevant to all four functions: calibration, preventive maintenance, troubleshooting, and repair. This conclusion is further substantiated by our respondents' ranking (in Table 18) of the skills and knowledge required of prospective BMET's. First and second place (separated by only two percentage points) were given respectively to troubleshooting and repair, and to knowledge of the way the equipment transforms an input into an output signal. Knowing how to operate the equipment ranked third. Of less importance (but still significant) is the requirement that a BMET have knowledge of the physiology, chemistry, and biology associated with the equipment on which he works.

TABLE 17

COMPARISON OF PERCENTAGE OF BMET'S PERFORMING MAJOR AND MINOR REPAIRS, PREVENTIVE MAINTENANCE AND CALIBRATION ON SPECIFIC BIOMEDICAL EQUIPMENT

	% BMET's Performing				
Type of Equipment	P.M.	Calib.	Major	Minor	N
blood-gas analyzer	44	47	50	57	200
autoanalyzer	33	35	43	44	188
blood cell counter	33	38	41	43	203
refrigerated centrifuge	41	42	51	53	190
spectrophotometer	39	45	50	53	218
flamephotometer	35	42	47	49	205
stills	36	36	48	50	198
gas-chromatographs	29	34	38	39	194
mass spectrometers	22	23	24	23	178
pH meter (or titrator)	39	48	50	51	209
balance: precision (mechanical)	28	34	35	35	193
balance: electronic	27	33	36	35	185
microtomes	28	29	36	36	198
microscopes	31	30	37	42	201
cardiac monitor	60	68	68	71	243
pacemaker (external)	51	57	61	63	231
EKG	64	70	72	74	250
defibrillator	60	61	66	69	239
alarm system	61	63	67	69	239
respirator (ex. Bird)	41	42	47	50	209
electrosurgical cauterizer	45	44	57	60	208
anesthesia apparatus	28	28	33	38	189
surgical pumps	44	44	54	54	207
heart-lung machine	30	28	33	35	167
X-ray equipment	32	33	38	39	198
scintillation counter	25	30	35	35	197
radiation monitors	25	30	36	38	192
scanner	26	28	33	36	188
prosthetic devices	9	11	15	15	176
analog/digital computers	24	26	31	32	197
refrigerators	25	25	32	33	189
dental equipment	26	26	33	36	160
air conditioners	21	20	22	25	177
sterilizer	39	41	51	53	206
dialysis systems	22	24	29	33	168
incubator: infant	45	48	54	56	180

TABLE 18

PERCENTAGE OF RESPONDENTS INDICATING IMPORTANCE OF PARTICULAR SKILL AREAS (BY INSTITUTION)

Skill Areas	Total	Companies	Hospitals
Have ability to locate and diagnose faults and repair the equipment.	40%	34%	44%
Have a knowledge of the manner in which equipment transforms the input signal into an output signal.	38	28	44
Have knowledge of how to operate biomedical equipment.	30	23	34
Have a knowledge of the physiological and chemical principles on which the input signal to equipment is generated.	20	13	25

Most biomedical equipment is extremely expensive. Schools will therefore want to keep to a minimum the amount they must acquire, or to which they might gain access through lease, rental, or cooperative arrangements with hospitals or companies. To develop guidelines for schools planning to purchase or borrow equipment, our respondents were asked, "If you were designing a BMET training program, assuming that you could select only five or six pieces of equipment to treat intensively in the program, which items would they be?" In making their selection, respondents used one or more of the following criteria:

1. Equipment which the BMET's worked on most frequently or which most often required attention.

2. Equipment which was representative of different departments in a hospital.

3. The newest, most sophisticated, complex equipment.

4. The only equipment the BMET worked on (i.e., in manufacturers).

5. Parts of equipment (motors, amplifiers, transducers, etc.) or test tools.

6. Equipment whose systems were such that if a BMET were thoroughly familiar with that piece of equipment, he could then apply the knowledge to a range of other equipment, ("If he can repair a color television, he can repair anything.")

7. Equipment whose systems were representative of the different components of equipment, ("If he knows this instrument he knows enough about electro-mechanics.")

The frequency with which specific items of equipment were suggested is shown in Figure 1(A). The spectrophotometer, cardiac monitor, electrocardiograph, X-ray, communications/T.V. equipment, and defibrillator stand out as clear choices. We should point out that respondents made most of their choices from our list which did not include communications equipment - this item, therefore, received "write-in votes" and it might have scored even higher if it had been listed.

As a means of verifying the list of equipment specifically suggested for inclusion in a training program, we derived a second equipment list from the data shown in Table 17: our respondents' estimates of the percentages of BMET's who carry out certain tasks on various items of equipment. Analysis of this data yielded a ranking of equipment reflecting both the frequency of the BMET's involvement with the equipment and the nature of the involvement - the type of task performed. This is also shown in Figure 1 as (B), compared with the choices of equipment for inclusion in a BMET training program (A). There are differences in the ranking, but a BMET trained on the first twelve or thirteen pieces of equipment suggested in (A) would encounter few strange items if he found himself working with equipment listed in (B).

FIGURE 1

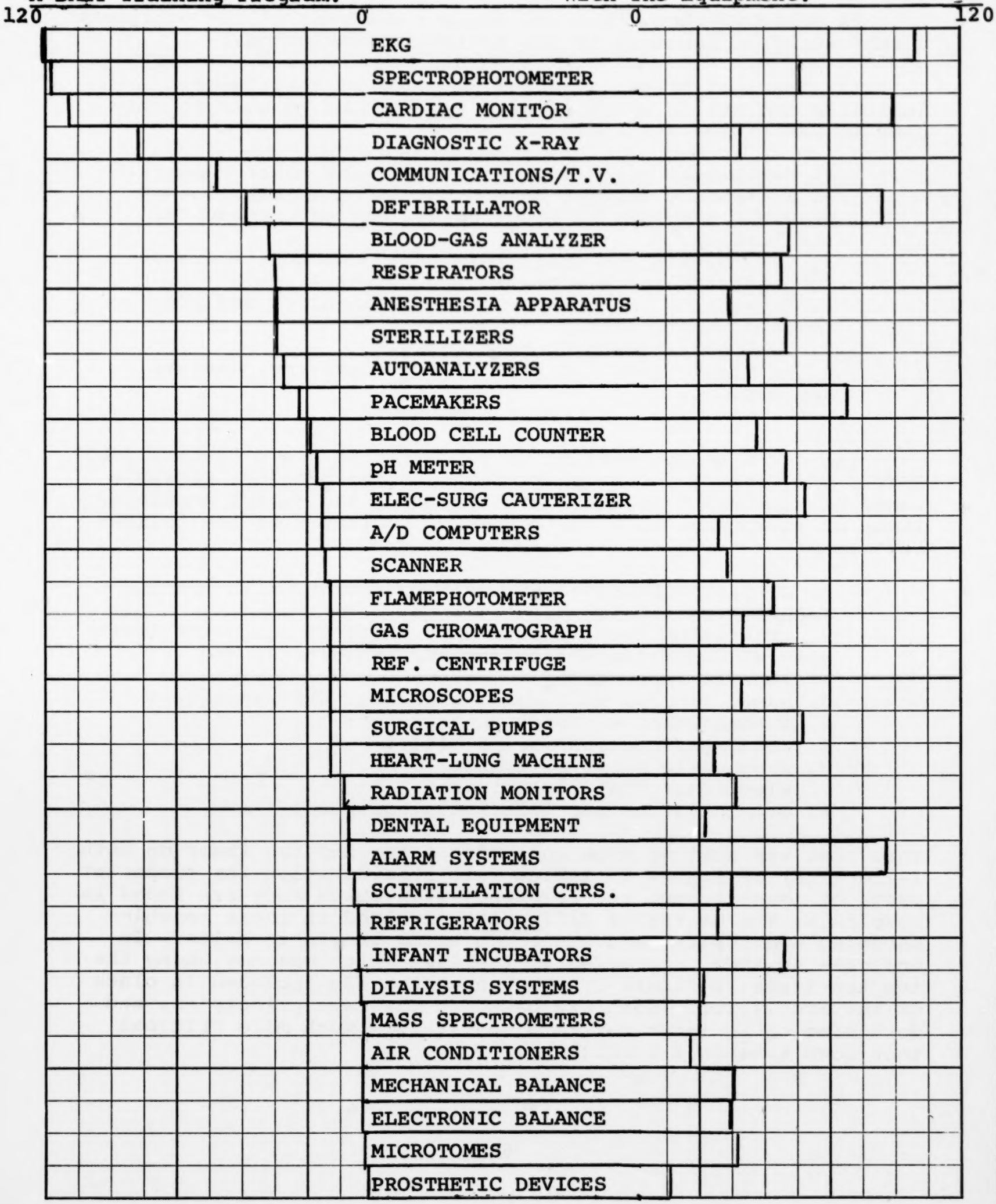
COMPARISON

A

Frequency Items Were Mentioned By Respondents For Inclusion In A BMET Training Program.

B

Ranking Of Items According To Our Analysis Of BMET Involvement With The Equipment.



In summary, then, this preliminary analysis of the equipment a BMET works on leads us to the following conclusions:

(a) The list below, arranged in order of importance, indicates the skills and knowledge a BMET must be able to draw upon in performing his work.

1. Troubleshooting and making major and minor repairs.
2. Instrument theory, with emphasis on integration of relevant concepts in electronics, optics, mechanics, and physics.
3. Transducers and their role in a component's transformation of input signals into output signals.
4. Procedures and standards for calibration and preventive maintenance.
5. Equipment operating techniques.
6. Related aspects of physiology, chemistry, anatomy, and biology.

(b) For a school setting up a program to train "generalized" BMET's and wishing to expose students to the broadest possible range of biomedical technology while using the fewest possible items of equipment, we would recommend inclusion of the following items:

1. cardiac-intensive care unit equipment (with special emphasis on the EKG machine);
2. inhalation therapy-pulmonary function equipment (with special emphasis on respirators, incubators, and anesthesia apparatus);
3. pumps (including vacuum, pressure, and surgical);
4. autoanalyzer or spectrophotometer;
5. blood-gas analyzer or ph meter;
6. diagnostic X-ray equipment;
7. electrosurgical cauterizer;
8. communication and television equipment.

This list was derived from analysis of the top ten items on both (A) and (B) of Figure 1, taking into consideration the component parts of those items, the frequency with which they are found in hospitals, the degree of difficulty involved in their troubleshooting and repair, and their projected growth in sales. In one case an item was added to the list which was not among the top ten items in Figure 1. The incubator was included in place of the sterilizer. Both are based on the same principles, and down time on an incubator in a hospital is much more critical than down time on a sterilizer.

(c) We believe this list constitutes a model "BMET equipment library" consistent with our survey findings concerning training and employment of BMET's nationwide in the spring of 1970. But for this very reason, it is also something of an "average" or "ideal" which should be adjusted to the real needs of local or regional employers as these needs can be identified and as they change with the continuing evolution of the BME field. For example, sales projections in the A.D. Little report (1969) suggest that equipment relating to patient monitoring, nuclear medicine, ultrasonics, and analog to digital computers should receive special consideration as candidates for inclusion in any BMET program which hopes to anticipate future developments.

OBSTACLES TO SETTING UP COLLABORATIVE TRAINING PROGRAMS

Although many respondents indicated that they would be interested in a collaborative BMET training program, we anticipate many obstacles. One of the primary obstacles is the lack of resources. We have encountered several community colleges that have had to postpone the start of BMET training programs because they could not obtain local or state funds. Furthermore, since the BMET has not been recognized as an Allied Health Profession under the Allied Health Act, an institution cannot presently obtain federal funding for BMET programs.[1] Organizing a training program usually requires a sizeable investment in expensive biomedical instruments and although some manufacturers have been very cooperative in either donating or lending equipment, many educational institutions have had to work with the most inexpensive (and therefore least complex) equipment - often outdated and insufficient in quantity and variety. One possible solution to the problem of obtaining equipment is increased cooperation and coordination among manufacturers, hospitals, and educational institutions, and the increased use of internships, which allow supervised students to work with equipment in hospitals or research institutes alongside BMET's.

A second problem along with their failure to see how they could benefit from collaborating in BMET training, is the unwillingness of medical equipment manufacturers to give out schematics, wiring diagrams, blueprints, and technical manuals. It is noteworthy that the Armed Forces programs are probably the only ones with complete diagrams of all biomedical equipment which they use in training. These were obtained by special agreement with the manufacturers and are kept under lock and key. Manufacturers' reluctance to release information is understandable when one reflects upon the case of the BMET who took the necessary schematics and diagrams from his employer, a manufacturer, and has since organized his own manufacturing company.

There is also considerable disagreement about the best form and content of a BMET program. Who should the instructors be: engineers, other technicians, doctors, instructors drawn from other existing departments in the college or institute, or a separate biomedical staff? How much electronics,

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1. The Allied Health Professions program authorizes developmental grants for projects to develop, demonstrate, or evaluate curriculum for the training of new types of health technologists. For a number of reasons, see Appendix H, a BMET training program is not eligible for funding under this act.

mechanics, and other aspects of the equipment should be stressed? How much physiology, anatomy, chemistry, math, and physics do the students need to repair equipment successfully? To what extent does the student need to study seemingly unrelated courses such ás general psychology and physical education? What is the best proportion of labs to lectures to clinical experience or internships?

There are also differences of opinion on whether the student's training should be generalized, exposing him to as much medical equipment as is realistically possible and leaving any specialization for on-the-job training; or specialized, giving him more intensive training in one group of equipment, such as ICU/CCU or X-ray. Lastly, there is lack of agreement on whether the BMET should be trained principally to repair equipment, or whether he should be primarily responsible for operating the equipment, understanding how to perform minor repairs and how best to handle major repairs (i.e., arrange for service contracts, call the manufacturer) and thus helping to alleviate the many operator-caused problems that many respondents mentioned.

Other obstacles to implementing BMET programs were encountered in our interviews. Some respondents simply did not believe that a BMET could be trained in a two-year program. Others were unable to conceive of the workability of a collaborative arrangement among hospitals, educational institutions, and manufacturers. Still other respondents, most notably those who had training programs or were planning them, emphasized the problems caused by the lack of information on how to organize a program,[1] the lack of curriculum, and the lack of good instructors. Representatives of institutions with existing programs also frequently mentioned difficulty in placing graduates or, more specifically, in convincing local hospitals to employ BMET's. This does not indicate, however, that jobs are not available, but rather that there are no good mechanisms for bringing the BMET graduates and prospective employers together. A training program will be successful only if it places its students in the types of jobs for which they were trained. To achieve this goal, there must be some form of communication or interaction between potential employers and trainers of BMET's.

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1. Respondents were seemingly unaware of the helpful guide on planning a health service program put out by the American Association of Junior Colleges.

While there may have been interest in collaborating in a BMET training program, there was sometimes no individual or institution in a city with sufficient enthusiasm, resources, or skills to initiate a program. In other cases, people did not sense a need for well-trained BMET's, or they felt that a formal training program was unnecessary because in their opinion a technician could be trained entirely on the job. This group constituted a very small proportion of our sample. Additionally, there is the problem of attracting students into BMET training programs. As in other emerging occupations, there is a lack of information about the field to stimulate interest.

Most of our respondents felt that there was clearly a need for good training programs producing competent BMET's; and there is also clearly room for a variety of types of training programs producing technicians to fill a variety of roles.

MANPOWER NEEDS

In addition to defining who the BMET is and what he does on the job, we felt that an integral part of our study included manpower projections. The techniques we used to arrive at these projections were not complicated,[1] and basically involved multiplying values of "average number of BMET's per hospital (company)" by "numbers of hospitals (companies)." Hospitals were grouped into different size ranges, but companies (manufacturers, supply houses and contract maintenance companies) were treated as a single group. Forecasting future needs in any area is always a subject for debate and critical evaluation, since projections vary depending upon the assumptions used. We have therefore decided to provide a range of estimates rather than a single figure to help account for the conditions of uncertainty with which we are working.

The results are summarized in Figure 2 which shows the range within which the number of BMET's employed in any given year is most likely to fall, the analogous figures for companies, and the aggregate for both hospitals and companies.

From a present base of 7100 to 10,500 BMET's, we project a rise in BMET's employed to 12,300 to 21,300 by 1975. Table 19 summarizes both the ranges and our most likely estimates for the years 1970, 1972, and 1975. These values indicate that the number of BMET's employed will approximately double in the next five years. This growth appears to be consistent with the projected doubling of the dollar sales of medical instrumentation.[2]

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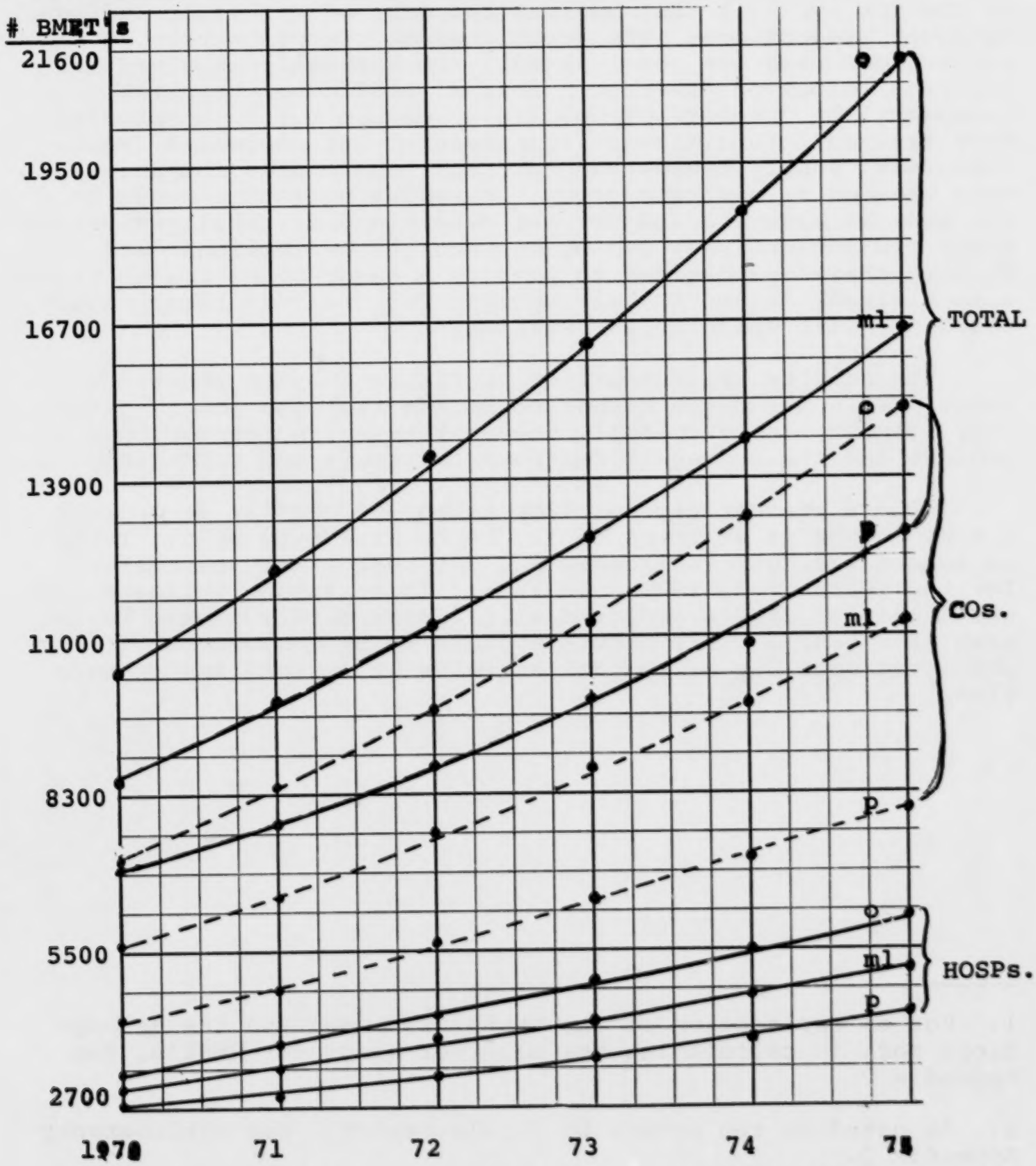
1. For an explanation of the techniques used and the assumptions made in calculating the manpower needs for BMET's, see Appendix O.

2. As cited in the Arthur D. Little Report. See Bibliography Appendix Q.

FIGURE 2

ESTIMATES OF THE NUMBER OF BMET'S WHO WILL BE EMPLOYED 1970-1975



o = optomistic ml = most likely p = pessimistic

TABLE 19

PROJECTION OF BMET'S IN '70, '72, '75 (BY INSTITUTION)

		HOSPITALS	COMPANIES
1970	Range	2700-3300	4200-7200
	Best Estimate	3000	5600
1972	Range	3200-4300	5600-9900
	Best Estimate	3800	7600
1975	Range	4300-6100	8000-15200
	Best Estimate	5180	11100

The number of persons who should be trained to fill positions as BMET's is somewhat larger than the yearly increase in the number of new jobs due to technician's leaving the field, retirement, and deaths. Incorporating these factors we have concluded that there will be a need to prepare about 1300 BMET's per year at present, with that figure rising to about 1900 per year in 1975.[1]

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1. At the present time, training facilities with which we are familiar graduate approximately 400 BMET's per year.

EDITORIAL COMMENTS

There are a number of issues raised in this report which require more extensive discussion than this study has provided. Based on TERC's experiences with this and the previous BMET survey, we would like to make a few editorial comments on them.

Employers, Costs, and BMET Roles

This report focuses on the role and training of the hospital BMET, and throughout there are indications that we clearly see a place for the BMET in any medium or large hospital. This is not to imply that we see no role for the company-employed BMET. We feel certain that a hospital can save money by having its own in-house technician, even if it continues to use company s services for most of the major repair work. This assertion is based on comments made by hospital-employed respondents; unfortunately we have no hard data on the economics involved. There appears to be a need for a comprehensive cost-effectiveness study of hospital equipment maintenance to determine the conditions under which hospitals should hire their own BMET's, collaborate in a BMET pool, or rely on manufacturers or contract maintenance companies.

Currently a definition of the BMET's role might be undergoing change. The use of sealed components, the increased possibilities of leasing equipment, and the ever-expanding variety and sophistication of medical instruments may require greater or lesser skill levels. One possibility mentioned often by doctors is that the BMET will be specialized by the type of equipment he works on, and his work will consist not only of repairing and maintaining this equipment, but also of operating it. This "operator BMET" (discussed on page 28) might spend 90% of his time operating the equipment, which would require more specialized skills in dealing with patients than is required of the straight BMET. We can see a place for this operator BMET in hospitals; many probably now exist. However, we do not see him displacing the straight repair BMET, but working together with him. The operator BMET might take care of most minor repairs and adjustments, leaving the major, often time-consuming repairs to the straight repair BMET.

One role for the BMET, not discussed in detail in the body of this report, is that of safety technician. Hospitals have become aware of the potential hazards arising from the use of many of the items of medical equipment referred to in this report. The dangers can arise from several sources: the way in which a particular piece of equipment is manufactured, installed or interfaced with other pieces of equipment; the way in which a particular piece of equipment is operated, attached

to the patient, or maintained. The BMET, as safety technician, could function in a number of ways to diminish these potential hazards: he could help the hospital establish safety rules which regulate the kinds of equipment which may be brought into the hospital; he could help take responsibility for screening all incoming equipment and making any adjustments or raising any questions to insure safe operation; he could make checks on installation, interfacing and use of the equipment to insure safety; and he could be responsible for educating the rest of the hospital staff in the safe use of their equipment.

If the BMET is to become a safety technician or an operator technician, if he is to keep up with his field as new, more sophisticated pieces of medical equipment are bought by hospitals, training facilities of a special nature must be available to him. We would suggest that no matter what the form, length, or location of a BMET training program, it should make provision for multiple entry levels. Such a program, permitting the continuing education of the BMET, would provide him with the means for keeping up with and advancing in the biomedical equipment field. Additionally a training program with multiple entry points allows for an individual partially trained in the field (such as the janitorial technician, a general electronics technician, or a medical technician) to pick up the few skills he may be lacking to become a BMET.

Communication and Interaction

It would appear that one of the key impediments to the productive utilization of BMET's is the lack of communication, and perhaps respect, between the medical and engineering professions. Until hospital administrators, doctors, nurses, and other paramedical personnel can understand both the capabilities of the BMET and his usefulness to the functioning of their hospital, the problems of the maintenance of medical equipment as well as of the recruitment of individuals into the BMET field will remain critical. We are not necessarily advocating certification of the BMET, since his role will probably continue undergoing change in definition. What we are advocating is increased interaction among those individuals who affect the BMET's role--the hospital administrators, the doctors and nurses, the hospital engineers, the medical equipment industry, and the educators or trainers of BMET's--in each local community, and on a national scale.

Locally, interaction among and within hospitals could lead to pooling of BMET's where this might prove advantageous, and to the more cost/effective use of these technicians in all health service institutions. Interaction among these institutions, equipment manufacturers, and technical educators could

ensure rapid and continuing adjustment of training programs to changing local employment needs at all levels.

Nationally, exchange of information and experience among many employers could lead to the clearer definition of BMET task performance standards, and the evolution of job descriptions and career ladders vital to recruitment of new BMET trainees. Similarly, better communication among educational institutions offering BMET training could help to eliminate redundancy in curriculum design, and in development of instructional materials. Teacher training programs might be organized on a regional basis. Instructional components used in any successful training program -- military, industrial, public or private technical institute -- could be pooled and reviewed. "Missing links" might be identified -- basic and specialized instructional units or modules most needed to match training capabilities to evolving employment standards on a national scale. Intensive development of such modules for rapid publication and national dissemination would then become cost/effective. As a result even the smallest in-house hospital BMET refresher course could have access to a "library" of proven instructional components from which to select those most relevant to its needs.

Furthermore, if the local and national interactions suggested here were systematized into an interactive network of interested employers and educators, any network participant could alert the others to new problems he could not meet with existing methods and materials. Through interactions of this kind, the network could evolve the capability to launch development efforts responding to, and even anticipating, more of the inevitably changing needs of the BMET and those concerned with his role in the improvement of national and local health care. For example, the network might plan and implement a cost/effectiveness study of the use of BMET's in hospitals, as suggested above.

Whatever the faults of this survey, or our errors in interpreting its data, our experience with it has strengthened TERC's commitment to experiment with the development and operation of an interactive network of this kind. In fact we hope this report, by stimulating BMET employers and educators to correct our errors and confirm our conjectures, may increase our own interaction with potential network participants; even more, we hope it will encourage them to interact with each other. We can and will find ways to encourage them to interact with each other. We can and will find ways to service these interactions, but it would obviously be inappropriate as well as impossible for their initiation in every community to depend on TERC or any other national organization. The excellent Guide for Health Technology Program Planning, published in 1967 by the American

Association of Junior Colleges, makes this point in the form of three assumptions:

> "Successful health technology programs can be established only if colleges build firm and continuing relationships with health facilities and health practitioner associations."
>
> "Each institution -- the college, the health facility, the health practitioner association -- commands resources vital to successful programs; each has a stake in educational programs for health manpower."
>
> "Within a community, any one of the institutions has a responsibility for acting as the catalyst to urge action on these programs."

On the strength of our survey experience, we feel these assumptions should apply to any BMET program, involving any institution, public or private, in any community, and we are looking forward to responding, as best we can, to the needs of those who share this view.

APPENDIX A. CRITIQUE OF THE INTERVIEW QUESTIONNAIRE

APPENDIX A

CRITIQUE OF THE INTERVIEW QUESTIONNAIRE

The content questionnaire instrument was developed on the basis of information about the BMET which TERC has been collecting since the beginning of the Phase I BMET project in 1966. Prior experience with nation-wide occupational surveys in the electro-optics and nuclear medicine field in 1969, guided the determination of the questionnaire design. Criticisms from experts in the biomedical equipment field in the Boston area were used to produce the final draft of the questionnaire. Overall, we felt that the questionnaire, despite its formidable length (many interviews took over an hour) allowed us to gather quite a log of useful data. There were, however, as on any questionnaire, a number of shortcomings.

We attempted to design a questionnaire which could be administered by an interviewer with little experience in the biomedical equipment field to a variety of respondents in both hospitals and companies. We had underestimated the ability of the interviewer to gain valuable information from a respondent through the use of open-ended questions, and thus had designed the questionnaire almost exclusively on the basis of closed-ended questions. Indications are that with a slight shift from closed to open-ended questions, we could have collected more information. We also might have gained more information had we developed two distinct questionnaires for companies and hospitals. A number of the questions were not relevant to both types of institutions--other questions could have been put in their place, had two questionnaires been used, which were directly relevant to the particular institution. These two questionnaires might have been further broken down to accommodate the variety of respondents--from BMET to hospital administrator.

Problems were encountered with individual questions for a number of reasons: (1) inconsistency in interpretation by interviewers and interviewees; (2) inability of respondent to answer; and (3) poorly worded/directed questions.

The complete questionnaire is found in Appendix R.

Inconsistent interpretations by both interviewers and interviewees of some questions can be attributed to several factors. Although the purpose and interpretation of each question was discussed in detail during the training week, there was no check on interviewers to see if they had absorbed this information--apparently some had not. Regardless of how an interviewer explained a question to a respondent, the respondent could easily have interpreted the direction of a question in light of his own particular experiences rather than the broader BME field. The wording of individual questions may not have been explicit enough, thereby misleading the respondent and/or the interviewer. The communication question (p.7), the question of the equipment list asking what kinds of repairs are beyond the technician's capabilities (p.9), and the career questions (p.12), were often open to misinterpretation.

Some questions were asking for information which the respondent could not always give either because he did not know the given fact asked for, or because the question asked for a variety of information such as what his "average" technician does, which he was unable to provide--he may not have felt that he had an "average" technician. The number and kinds of BMET's in other departments in his institution (p.4), the year in which the institution first employed a BMET (p.13), and the education and occupational backgrounds of his technicians (p.15) were questions to which several respondents had no knowledge of the answer. The percentage of time a technician spends on a number of functions and components of equipment (p.5), the job entry performance levels expected from a recently hired technician (p.10), the number of technicians a respondent expects to employ in 1975 (p.13), were questions with which respondents had a great deal of difficulty because of the seeming intangibility of the answer.

A few questions were poorly worded or poorly directed such that they elicited very little information. The most obvious of these was the question attempting to determine the order in which a series of events occur when a repair is accomplished (p.3). The wording of the question, plus the closed nature of possible responses, resulted in data which is relatively meaningless. The question asking for the set routines of the technician (p.5) with some rewording might have given us greater insight into what the BMET actually does day by day on the job, but as it stands, it helped us accumulate little data. We asked the respondent if he felt his institution would be interested in helping to set up or hire the graduates from a collaborative BMET training program at a local community college (p.16). It was easy for a respondent to answer "yes" to both questions without really understanding the implications for commitment that a "yes" answer has. The wording of the ques-

tion allowed us to accumulate a lot of seemingly positive data which is in fact quite useless.

Despite the problems with the questionnaire, we are satisfied that it provided data sufficient to accomplish the objectives of the survey.

APPENDIX B. THE TRAINING WEEK

APPENDIX B

THE TRAINING WEEK

The training week was a rather intensive five-day period the week before the interviewers were to go out on their interviewing circuit. The intent was to provide the interviewers with the maximum amount of information about TERC, the biomedical equipment field, the purpose of the survey, and its relationship to TERC's entire BMET project, as well as providing them with certain interviewing and coding skills. While most of the interviewers had previous survey research experience, in general they were only casually acquainted with the biomedical equipment field prior to the training week.

The first day of the training week served as an introduction to the entire project. The Project Director discussed the past history of the BMET project at TERC, including a description of the manpower-needs survey carried out in 1967 and the two test BMET training programs set up with the help of TERC at Springfield Technical Community College, Springfield, Massachusetts, and at Texas State Technical Institute, Waco, Texas. He mentioned the role the survey report would play in developing an interactive network among trainers and employers of BMET's as well as in developing curriculum modules for BMET training programs. TERC's in-house biomedical engineer lectured on the functions of a wide range of biomedical equipment as well as on how a BMET might function in a hospital. A discussion was held on the general interviewing process, including how to locate a BMET in a hospital or company. The interviewers practiced locating BMET's by role playing phone calls to hospitals and companies. Reading materials were passed out.

The morning of the second day of the training week was spent touring a local hospital, with emphasis on seeing specific kinds of biomedical equipment. During the afternoon the interviewers went through the questionnaire, discussing the purpose of each question to give them an idea of how to interpret specific questions and what kinds of responses to expect.

The third day each interviewer conducted two interviews. Where possible, one was at a hospital and one was at a company.

This served not only as practice in a familiar city for the interviewers, but also as a pretest of the questionnaire instrument. This pretest allowed us to make some necessary minor changes in the questionnaire.

With a number of interviews completed, we were able, on the fourth day, to solve many problems which could be encountered in an interview situation on specific questions in the questionnaire. We arrived at a general consensus on how to interpret questions which seemed ambiguous or misleading. TERC's programmer explained the coding procedure, and the interviewers coded, under supervision, the questionnaires which they had completed on the previous day.

The final day of the training week was spent reiterating the purpose of the study, the interviewing process, how to use contact lists, how to locate BMET's, how to interpret/explain specific questions on the questionnaire, and how to code the questionnaire. Travel plans were finalized and interviewers left to interview--five of them for three weeks; five of them for two weeks.

A number of positive comments can be made about the training week, but not without also mentioning its inefficiencies. Interviewers seemed to have gained a grasp of the interviewing process, including how to locate BMET's. Very few problems arose during the interviewing process which interviewers were not able to handle. They seemed to have been sufficiently sensitized to key issues (conflict between doctors and engineers, safety, status of the BMET) to be able to pick up a large quantity of interesting comments not directly elicited on the questionnaire. While the overall interviewing process went smoothly, a number of difficulties arose relating to specific questions on the questionnaire. Although the purpose and interpretation of each question had been gone over several times during the training week, it was not possible to maintain consistency during the interviewing process. Unanticipated responses required interviewers on the road to develop their own interpretations on a number of questions (see Critique of Questionnaire, Appendix A). A combination of the bulk of information dispensed during the training week, and the lack of a mock interview carried out in front of all the interviewers may in part explain why interviewers interpreted some questions in a variety of ways. An equivalent comment can be made about the coding--coding errors were rampant in some sections of the questionnaires because of insufficient time to explain in detail how to interpret every single code. Perhaps if the coding interviewers completed during the training week had been more carefully edited, some of the coding errors could have been avoided.

It was the general feeling that the training week was helpful in preparing interviewers. Perhaps just a bit more emphasis should have been placed on actual interviewing and coding experience, with some built-in mechanisms for checking on what individual interviewers were not grasping.

APPENDIX C. THE PROPOSED INTERACTIVE NETWORK FOR BMET EDUCATION

APPENDIX C

THE PROPOSED INTERACTIVE NETWORK FOR BMET EDUCATION

Our interest in studying the BMET is ultimately to improve and expand the educational programs open to him. We hope that our data will reach all those who can influence his education. We also want to insure that whatever progress is stimulated by the data is maintained, amplified and translated into educational curricula. We believe that perhaps the most effective way of doing this is to keep all those interested in BMET education talking to and interacting with each other; and so we propose the formation of a network of such people: technologists, manufacturers, supply houses, hospitals, maintenance companies, research centers, educators, professional associations and educational publishers. We should mention that we have been much encouraged in this idea by the positive responses of a number of educators who were asked whether they would find such a network useful and whether they would participate in it.

The network would have two main functions: generating information and promoting its utilization. We would collaborate with interested parties in order to gather and analyze data of importance to the education of the BMET. We would also disseminate significant findings, and maintain a pool of resource materials. Following the priorities expressed by the educators referred to earlier, we would expect the network to focus initially upon information on:

- -new instructional materials and methods
- -relevant technological development
- -general patterns of opportunities for employment for graduating BMET's.

The aim of the second function - promoting the utilization of the data and resources - would be of course to insure that education adapts to technological evolution as rapidly as possible. Following expressed priorities again, we would expect the initial focus to be on:

-developing and up-dating instructional programs and materials
-locating and promoting financial and material assistance.

Since the network would be fuelled by interaction among its participants, the latter would need to be actively committed to the development of BMET education. We would not expect many people from each of the interested sectors to be so committed, and anticipate rather that the network would be composed of relatively few, but unusually active persons. These people would be invited to help define problems in BMET education, to gather information on them, to propose solutions, and to evaluate the solutions offered by others. We would anticipate, too, that, where a number of participants reside close to each other, they would form miniature networks to work on local problems

Opinions of Some Educators on the Proposal for an Interactive Network

In April, 1970, 136 persons in the USA and Canada, who had expressed interest in education for biomedical equipment technology, were asked their opinions on the idea and possible functions of an interactive network. Thirty-three replied. Of these, five actually run programs for potential BMET's, and ten plan to do so. The remaining eighteen do not propose to do so, but nevertheless have an interest in the promotion of technical education. Although the number of responding educators actually involved in BMET programs is small, it does constitute all but two of the existing or planned programs that we have so far been able to locate in the USA and Canada: their opinions thus carry considerable weight.

Table I reflects what the educators thought would be "Very Important" functions for the Interactive Network.

TABLE 1

Respondent Code

BMET (O) - those currently operating educational programs for BMET's

BMET (P) - those planning or considering such programs

(I) - those neither operating nor planning such programs, but having a strong interest in technical education.

Function Code

a. developing and up-dating instructional materials
b. testing and evaluating new instructional materials
c. circulating information on new instructional materials
d. circulating information on relevant technological developments
e. locating and promoting financial/material assistance
f. developing materials for the recruitment of students
g. publishing employment opportunities and projections
h. following up graduates in their careers

Percentages are calculated to the nearest round figure

Percentage of Respondents Rating Functions "Very Important"

	Respondent								
	BMET(O)		BMET(P)		(I)		Total		Rank
Function	#	%	#	%	#	%	#	%	
a	3	60	10	100	14	77	27	82	1
b	1	20	5	50	9	50	15	45	6
c	2	40	7	70	13	72	22	67	2
d	2	40	9	90	10	55	21	61	3
e	3	60	8	80	7	39	18	56	4
f	3	60	5	50	6	33	14	42	7
g	5	100	6	60	5	28	16	48	5
h	3	60	6	60	5	28	14	42	8
Number of Respondents	5		10		18		33		

In aggregate then, the functions might be ranked in priority as follows:

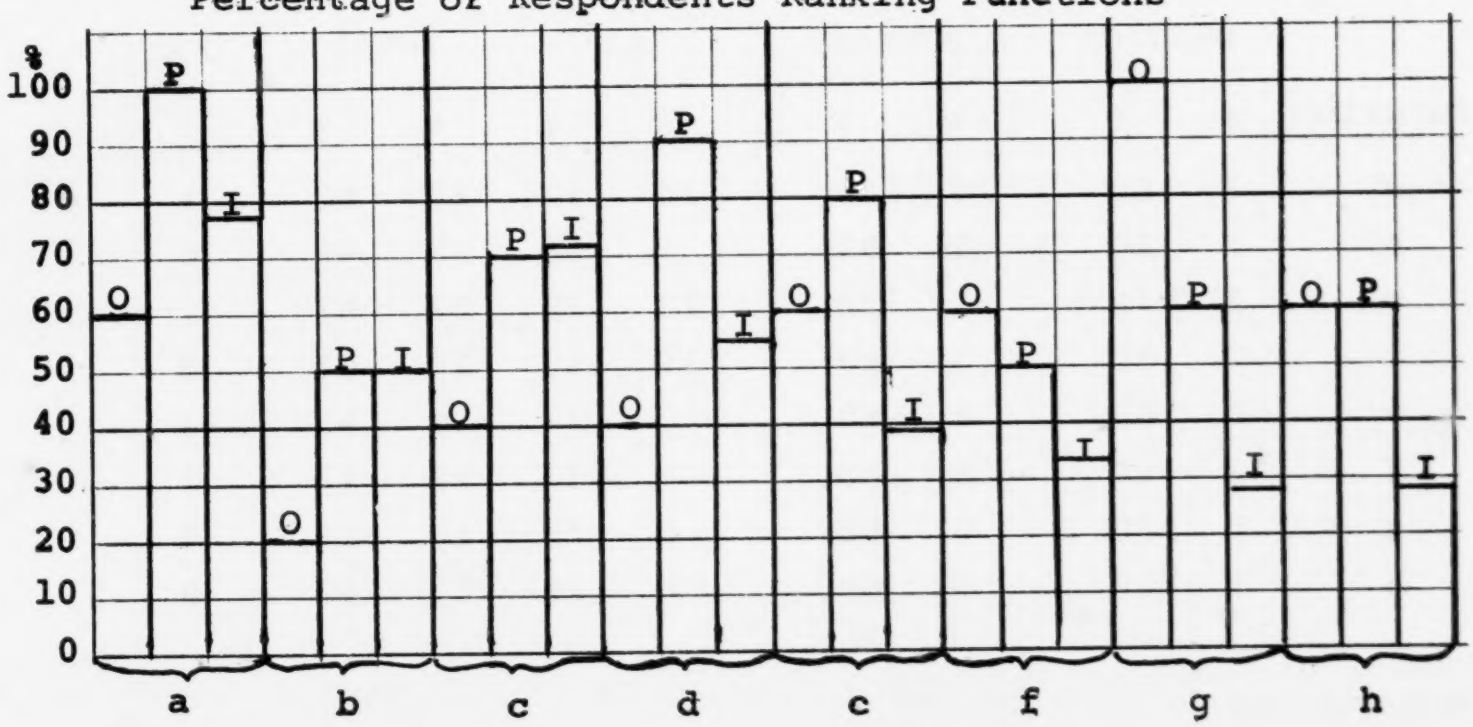
1. (a) developing and up-dating instructional materials
2. (c) circulating information on new instructional materials
3. (d) circulating information relevant technological developments
4. (e) locating and promoting financial/material assistance
5. (g) publishing employment opportunities and projections
6. (b) testing and evaluating new instructional materials
7. (f) developing materials for the recruitment of students
8. (h) following up graduates in their careers

(It should be borne in mind that, despite this internal ranking, all the functions are rated "Very Important", i.e. even functions (f) and (h) were felt to be very important by 42% of the responding educators).

However, there are important differences between the groups, which probably reflect their differing immediate needs. Table II illustrates this.

TABLE II

Percentage of Respondents Ranking Functions



BMET(O)'s are unanimous in stressing the importance of publishing employment opportunities and projections, and most of them are concerned about recruiting students and following-up graduates. A majority are concerned about better instructional materials, and obtaining financial and material assistance; but only a minority stress the evaluation of new materials and the need for information on them and on relevant technological developments.

Most but not all BMET(P)'s are concerned with the employment and follow-up of graduates. However, their chief concerns are the development of instructional materials, information on technological development and the location of assistance. (All three of these items are, of course, critical to the establishment of new programs).

(I)'s are unanimous on no Function: their greatest measure of agreement is on the importance of developing new instructional materials and informing people of them. Recruiting and placing and following-up students are stressed by less than a third of them, while less than half think that finding assistance for programs might be important. Their interests, in other words, are strictly academic.

In order to give more account to the needs of those actually running or planning BMET programs, weights were given to the responses: three points for each 10 per cent of BMET(O)'s, two points for each 10 per cent of BMET(P)'s and one point for each 10 percent of (I)'s. The priorities then change as follows in Table III.

TABLE III

Ranking of Functions According to Weights

	Respondent				
	BMET(O)	BMET(P)	(I)	Total	Rank
Function					
a	18	20	8	46	1
b	6	10	5	21	8
c	12	14	7	33	5
d	12	18	6	36	4
e	18	16	4	38	3
f	18	10	3	31	7
g	30	12	3	45	2
h	18	12	3	33	6

In coordinating the operation of the Interactive Network, TERC will be guided by these priorities.

APPENDIX D. READERS COMMENTS

APPENDIX D

READERS' COMMENTS

After completing the draft of our survey report, we sent copies to people whom our interviewers felt were interested and knowledgeable in the biomedical equipment field. We asked them to examine the report for its objectivity, consistency, accuracy, and representativeness of the field. Following is a sample of the comments we received. The complete list of Outside Readers can be found in Appendix S.

The physician will, as candidly stated in the report, almost always deal in some way with the quality of the data provided by an instrument, and build his criticism around that. He will understandably avoid discussion of the instrument's function or operating principle; however, in most cases will refuse to admit his inability to operate the instrument accurately. The engineer, in my experience, will stress ultimate sophistication, but, as a rule, will be unaware of what is considered good patient care within a hospital. For example, some Cardiac Care Unit planners would have several types of devices at the bedside for measuring all kinds of parameters, such as arterial and venous pressure, cardiac out-put indexes, etc. However they forget that the acute cardiac patient needs, almost above all else, rest, not several types of electrode systems, and various intravascular devices. This situation may seem difficult to resolve, because there is need for both better patient care and more sophisticated equipment in our hospitals. It is my opinion, therefore, that the BMET is needed to work with both the physician and the engineer toward that end, helping to maintain a balance between the two disciplines, in addition to applying the instrumentation..... This conclusion leads me to my only criticism of TERC's report: the responsible hospital administrator reading the published report should be moved to near panic when he finds out how sophisticated and problematic biomedical equipment is getting. Some, I am sure, will take decisive action, probably implementing an already-trained BMET, or selecting an individual to be sent to a place where training is available. However, from my experience with these matters, I believe that two problems

will arise which I am sure plague the BMET even now: [1] there will always be a problem between BMET and physician-nursing staff unless specific lines of communication, mutual respect, and individual authority are set down by the hospital administration. [2] definite personnel training programs in close cooperation with the BMET are essential, or the BMET will be quickly discouraged by having to fix items that would not be broken if they were used properly. These two problems, as I am sure is evident, are closely allied, and I did not get the impact about them from the TERC report that I thought I would. What I am suggesting is that some people reading the report will not understand the staggering importance of some of the findings, because of inexperience with the whole situation surrounding the medical instrumentation industry.

Rudolph A. Lucente

It comes as no surprise that such a large percentage of "janitorial types" are employed in our hospitals. Non-technical hospital administrators are prone to use their employees in whatever capacity they consider economical. The educational requirements, as well as previous experience required, indicate only a minor concern with the overall problem of providing reliable, safe, and efficient maintenance in the hospital. It is interesting to note the relatively small difference in salary between the "janitorial" and "specialized" BMET's. I think, as the report infers, that this reflects the hazy and muddled understanding of current technology on the part of the hospital administration. The relationship between the BMET and the doctor is not nearly as critical as that between the BMET and the nursing staff. The doctor seldom spends more than a few minutes in contact with the BMET, while the nursing staff is present constantly. One area in which the report appears to be lacking is that of patient safety. The BMET will inherently fall heir to the responsibility for seeing that the equipment purchased meets basic safety requirements, and the existing equipment is maintained in a safe condition, and used safely. The potential hazard to the patient caused by unsafe equipment can substantially increase the liability to the hospital, making it likely that the hospital will employ a "token" BMET, if only to show that it is excercising reasonable caution and diligence in behalf of patient safety. There is a gloomy aspect to the BMET as a career. High technology seems to be insignificant in the medical community. The space program may have changed some of this, but the physician still regards electronics as color TV and stereo, only somewhat more complex than a Waring Blender. The relatively few physicians who recognize the potential advances which can be made by utilizing advanced instrumentation

must play a role in improving the understanding of instrumentation throughout the profession. The BMET report will, I believe, provide valuable evidence to industry that their role must also include improved service to medicine. It should also provide an incentive to local colleges to provide the necessary educational background to those interested in a career in bio-engineering. Few programs are available, and those which are available are not generally suitable to the potential BMET, because they are aimed at post-graduate course work, leading to degrees in bio-engineering.

John H. Maness, P.E.

The projected doubling of BMET manpower in hospitals during the next five years, although desired and necessary to maintain the increased profusion of complex equipment in satisfactory condition, seems to be optimistic. The trend is indeed upward, but all too gradually. Industry has outstripped the medical profession with its barrage of sophisticated instrumentation; nor does the lethargy of hospitals in recognizing the need for qualified BMET's afford much hope that the health field will very soon match the giant strides of industry in this regard.

Thus, the "growing awareness" of hospital administration "to the cost/benefits of employing BMET's" is painfully lacking. Perhaps the greatest impediment to such progress is the complete lack of a baseline since so few hospitals have meaningful data verifying the categorical cost of their maintenance. The purchase of new types of medical equipment will most surely grow but--until hospital purchasing departments are perceptive enough to incorporate their requirements for technical service literature, peculiar replacement parts, and special tools into their purchase orders--service efforts will continue to be thwarted.

The TERC BMET Study, probably due to budgetary constraints, covered only major metropolitan centers--centers, not too oddly where manufacturers are well represented from a service standpoint. But what about out of the way places. Is the problem to which we address ourselves really not more severe? For, to such hospitals, no convenient manufacturer's service is available, their budgets are relatively small, and compact proprietor-type service organizations are only occasionally available.

Robert D. Luchi

In reviewing the report, I attempted to interpret the data as it pertained to my experience in the BMET field. I am a graduate civil engineer who heads, among other departments, the Maintenance and Engineering department of a 300 bed general, acute care hospital. The institution does not carry on any extensive teaching or research programs.

Within that department is a young operating (boiler) engineer who possesses a B.A. degree from the University of Minnesota and has been attending a two year evening course in radio and electronics. About 1 year ago he expressed an interest in maintaining and repairing our cardiac monitors, which until that time, had been served by a manufacturer's representative. During the past year, as he has gained confidence, knowledge and experience, and after attending a two weeks maintenance course by an equipment manufacturer, he has undertaken more and more BMET-type work. He now spends approximately 75% of his time accomplishing BMET functions. I would categorize him as having recently graduated from the "JANITORIAL" to the "SPECIALIZED" type. With his present rate of progress, he could conceivably develop into the "GENERALIZED" type within a year or two.

My experience with this young man substantiates the conclusions drawn in the report. The problems he faces in his day-to-day work; the equipment on which he works; the nature of the maintenance, repair and modification work he performs; his frustrations; need for manufacturer's drawings, parts lists, etc., all parallel the problems brought to the surface and discussed in the report.

Small hospitals are not alone in this possibility [sharing a pool of BMET's]: Throughout the nation, there is a growing trend towards "centralization" and the "sharing of services." Four general, acute care hospitals in the Twin Cities, each within the 300 to 500 bed size range, have recently pooled their resources to operate a single laundry, closing down four separate laundries in the process. These same four hospitals have pooled their purchasing and warehousing functions and are now considering several other areas which might eventually be consolidated to reduce operating costs. The possibility of establishing a single BMET department to serve all four hospitals is a logical eventuality. Fewer BMET's; less test equipment; fewer repair parts (assuming some standardization were to result); greater opportunity for on-the-job training, etc. are possible benefits.

George W. Burton

I realize in the first portion of the manual that you were discussing the various individuals that your personnel interviewed. I would like to see it made very clear that the student that enters the field of BMET will not end up as a "Janitorial Type". It is in my opinion that a BMET would be a highly specialized and professional person.

Under Professional Affiliations, I feel the technician should have some training of hospital techniques. There are many: for example, the technician should be familiar with Isolation Techniques in the hospital. If he is called upon to repair a piece of equipment that is being used in a patient's room that is on Isolation he must know proper techniques for entering and leaving the room in order to protect the patient and himself.

Marvin Lough, A.R.I.T.

Specialized personnel who can operate the equipment properly put maintenance cost for hospitals at a minimum. I find the equipment that I am directly responsible for operates longer and more efficiently. I can tell when a small problem shows in the equipment and fix it before it becomes major. I am forced to take this procedure only because hospitals will not go to the expense of a parts department and costly calibration equipment. Recently doctors have noticed our standards are requiring a higher degree of accuracy. I am trying to prove that sending equipment out for calibration is time consuming and expensive in the long run. My assistant and I are working on a way to acquire calibration equipment for our oscilloscopes and meters. We have certain doctors supporting us, so I think our chance for expanding to a full calibrating and repair department may not be completely out of the question. This means hiring more BMET's for our department so the need is there for a school of the type which I hope you are considering.

I recently went to a manufacturers work-shop where they gave me a very good course on maintaining their equipment in C.C.U. monitors. I found this very educational, not only for learning their equipment but the different types of people taking the course. They all fell in your three basic catagories, but not many fell in the second and very few fell in the third. So the second and third catagories need very badly to be filled. This group consisted of about thirty-five men.

Henry J. Kopchinski

Your survey most adequately pointed up the desperate need for programs to assure future availability of soundly trained technicians in the medical equipment field, and even more so indicated the confusing state of the art that now exists.

It is my belief that the medical products industry will be forced for some time to come to bear the major portion of the task (and cost) of training BMET's because of the obvious lack of educational facilities and programs offered by our society. Your survey report points this out most dramatically in the section entitled, "How BMET's are Trained," and in Appendix K. I concur wholeheartedly with most of the findings in your survey/report but would point out the following:

The Survey repeatedly stated that hospitals (BMET's) were hindered by manufacturers and suppliers not providing schematics, circuit diagrams, spare parts and specialized repair tools. Most manufacturers tend to shy away from providing such unless pressured into it by the hospital because of the legal hazards involved in unskilled hospital repair people attempting to repair complex products without sufficient training or background. Unfortunately, schematics, tools, and parts are just the beginning of any proper repair and we have all been burnt many times by inadequate repairs over which we had no control. However, the hospital who has competent service talent should insist that proper technical support literature, tooling and spare parts are available prior to purchase of costly medical equipment. This should be one of the criteria of acceptable purchase.

Throughout your survey report I noticed a lack of representative mention of pneumatic equipment as compared to electronics, optics and mechanics. It should be noted that the Inhalation Therapy, Respiratory Care, and Pulmonary Function Departments of most modern hospitals represent an equipment expenditure and inventory equaling or exceeding most other departments (including some X-ray and Laboratories). Modern hospitals are piped for medical gases (Oxygen, Air, N_2O) and Vacuum, and secondary equipment that attaches to this piping system (Flowmeters, regulators, nebulizers, humidifiers, etc.) plus respirators and IPPB equipment constitute a considerable equipment load and are all pneumatic in nature.

Robert Bevan, Jr., A.R.I.T.

I agree with the list of equipment recommended for BMET training but would include repair of special cables and the associated use of plastics. Manufacturers are prone to make cables with molded fittings and at first glance are deemed to be not repairable. With a skill and small knowledge of plastics these overly expensive items are able to be repaired. It is one of the most frequent items of equipment failure.

Earl A. Sullwold

One thing brought out by the study that was interesting to me was the fact that the company service technicians were not really better trained or had higher skills than many of the in-house technicians. I am afraid most hospital administrators believe that they could not afford this "highly skilled" mechanic when in reality they could not only afford but could utilize him in many areas other than the ICU units, for instance.

In regard to a BMET training program I would concur with the majority of the respondents in that the program should consist primarily of electronic training, trouble shooting, circuitry, etc. I further believe a program of one half day spent in classroom theory with one half day in the hospital area actually working with trained technicians (these would have to be skilled) would produce a better trained individual, at least for hospitals, than one that had all schooling with labs, etc.

One point I would like to stress is the term "janitorial type". I believe this is a poor choice to represent anyone capable of working on some electronic equipment even though his skills are somewhat limited. I am afraid that administrators might read the report and get the idea that poorly skilled janitors can take care of their cardiac equipment. Secondly, it down grades the position and makes it less attractive to prospective and presently employed BMET's. I would suggest a term such as "utility type" or some other term more descriptive and less degrading.

Robert C. Paul

There are some 5000 different types of medical devices in the average hospital if one includes lamps, beds, radios and bedpans, etc. Some 10% of them are electrically related in some way. Therefore, your list of 36 must be considered as representative, or in some cases as "lumped." For example, surgical pumps could include a variety of pumps used in the

operating room as well as those used in the patient room. The cardiac monitors class could include pulse, respiration and blood pressure monitors. The pH class could include pO_2 and pCO_2 meters and monitors now just coming on the market. On this basis, I think your list is sufficiently complete to indicate adequately the scope of the job of the BMET.

Many of your responses on the training of the BMET were typical of the replies we get when we ask industry about the training of engineers. They are based upon the immediate situation with very little thought given to the future. The BMET cannot be expected to be adequately trained in biological science, electronics, service techniques and specific devices. He must be given a basic education which will enable him to adapt to the situation when under the supervision of an adequately trained biomedical engineer. The BMET should seldom be expected to design, this is an engineering job. Of course, individual men may achieve the capability of design through reading, experience and on-the-job training. In making this comment, I am indicating that I think your survey is somewhat lacking in its examination of the problem of the desired training for the BMET. It emphasizes too much the existing training. Incidentally, my experience has been that in general, the military BMET is well trained in the technical aspect, but often lacks the niceties which go along with the job in the civilian hospital.

One item which was not emphasized enough, it seems to me, was safety. In this regard, several facets exist. There is the problem of electrical safety where the quality of the workmanship is all important. The BMET should be much concerned with this. Secondly, there is the problem of determining whether the device is working precisely, i.e., whether it is doing exactly what it is intended to do. Both of these problems are solved only if there is adequate on-the-job training and supervision of the BMET by the bioengineer.

Paul E. Stanley

The technical tasks [See Table 12] do not show important differences between levels of technicians. Again using electronic equipment as an example the list could include:

check electric power circuits
check signal cables
replace modules
check and replace tubes

use test instruments to locate faulty circuit
replace circuit card
trace signals and find faulty component

Robert B. Spooner

The report is complete in the one specialization of equipment repair in Biomedical Technology. We at Grossmont feel that the BMET, as defined by your report, is just one segment of Biomedical Technology. I would hope that you would be able to expand your field of survey operations to encompass other areas, especially that of the Biomedical Technician working in the cardiopulmonary, physiological monitoring for research, and in specialized areas of cardiac catheterization, lab operation, computer operation involved with body signal monitoring from ICU or CCU monitors, etc.

W. È. Dellegar

One specific, major criticism of the overall Report is the almost complete disregard of equipment installation. In the businesses in which we compete not only is there the after sale service aspects that require consideration but equally important the original installation, calibration and check-out of the equipment prior to turn over to hospital personnel. This short coming in the Report from our viewpoint was probably brought about by the questionnaire, which was utilized for both the hospital and manufacturer through different surveys, each designed to ferret out the differing areas of interest and problems inherent to the hospital or manufacturer. Equipment installation, therefore, is a major consideration which needs exploration from the manufacturer's viewpoint.

W. L. Bloom

Your conclusion that a strong electronic background is necessary shows up in all the sections of the survey. I agree if we are talking about a one or two man department. In a larger instrumentation section I do not think all of them have to be strong in electronics. I am assuming that just knowing how to use a VOM meter or a scope doesn't qualify as a strong electronic background. From the data in Table 10 (maintenance on specific instruments) I can see just as strong a need for a background in mechanics, chemistry, physics, and optics. As a supervisor of a four man department dealing with clinical and research equipment I find that

at least 80% of the problems are mechanical or very simple electronics such as replacing a fuse or a tube. One fairly good electronics man can handle our major electronic problems.

The survey shows an increasing number of BMET's in hospitals projected through 1975. The fact that there are some now and that the field is expanding can be interpreted that the manufacturers and supply houses are not furnishing the field support at a reasonable rate and within a reasonable time. Most hospitals are forced to rely on their own instrumentation departments because of excessive down time and the high cost of service contracts. This possibility should be examined more in your survey.

Gaylord M. Twite

It appears that BMET's will have to form an association much like many other hospital people in order to be recognized for their ability and status. Many of the medical associations do a good job in promoting the professional image and showing their members how the respect is won.... I suggest you recommend an association be formed to promote the fields.

Carlos Martin

Your evaluation of the frequent references to the difficulty experienced in obtaining manufacturers' diagrams, schematics, maintenance literature, etc....should consider the probability of an administrative failure by the BMET. Most manufacturers will furnish this data when it is requested, particularly when the request is incorporated in the purchase order for the equipment. The BMET of the future must have the administrative ability to obtain the reference material referred to above and the repair parts required to maintain the equipment.

A brief summary of the cost of contract maintenance or commercial repair should be included to provide a reference point for cost comparison of BMET maintenance and commercial maintenance. The labor cost of most commercial repair is now between $22.00 and $58.00 per hour in this area. This comparison would facilitate the establishment of the BMET's relative position.

Carl J. Ogden

I contend that much more time is spent on the supply and administrative procedures than your figures indicate. I think this was misinterpreted by the BMET. Even the janitorial type has to identify to someone what part is required for the repair. If your figures truly reflect the time spent on supply and administrative procedures then this could account for a lot of down time for equipment and poor feelings toward the BMET and why some areas prefer company service to in house repair.

I think this is one reason you found the number of people without degrees working in the BMET. You can't graduate as a BMET if there isn't any place to graduate from. I also think that the schools will find that the type of person dedicated and working as a BMET will require more than most schools offer at his time before they are willing to spend two to four years getting a degree. Many BMET's I'm sure found that the colleges offered little in their programs that would sustain them in their career as a BMET. Most I'm sure cut short their college to seek the required subjects and experience at technical institutions as was available to them. A clear definition of Biomedical Equipment must come first.

Paul L. Attwood

APPENDIX E. REPORT ON SURVEY QUESTIONNAIRE ON BIOMEDICAL EQUIPMENT REPAIR IN HOSPITALS

APPENDIX E

REPORT ON SURVEY QUESTIONNAIRE ON BIO-MEDICAL EQUIPMENT REPAIR IN HOSPITALS

This report[1] based on a survey of hospitals across the country, is part of the Technical Education Research Center's continuing inquiry into the current status, need for, and training of Biomedical Equipment Technicians (BMET's)[2]. The central areas of inquiry were: (1) how do hospitals organize the maintenance and repair of medical equipment, (2) how many and what types of hospitals have now or plan to hire BMET's, and (3) what emphasis do hospitals place on medical equipment maintenance and repair. The questionnaire[3] used in the survey was devised in discussions among TERC staff, and with hospital administrators in the Boston area. It was sent to over 1,000 hospitals in our larger cities listed in the current American Hospital Association Directory. Two hundred and forty-eight replies comprise the basis of this report. Besides data on the questionnaire, certain data was drawn from the directory of the American Hospital Association, including hospital bed size, budget, and type of medical services offered. Such data also helped to check the reliability of responses on the questionnaire.

PART I - FREQUENCY DISTRIBUTIONS

City and region - Respondents were from all of the twenty-four largest cities and numerous smaller cities in the United States, from all nine medical regions (as defined by the American Hospital Association) with little pattern of under- or over-representation of particular cities or regions. More

1. This report is a summary of a more lengthy report which is available by writing directly to TERC's Cambridge office.
2. Technicians whose primary responsibility is the repair and maintenance of biomedical equipment.
3. A copy of the questionnaire with response frequencies is found at the end of this report.

respondents came from the larger cities with more hospitals.

Type of Hospital - The sample included 115 (47%) teaching hospitals affiliated with medical schools and 57 (23%) research hospitals. Eighty-five percent of the respondents offer general medical services, the rest being specialty hospitals. Among the latter, about one-third are psychiatric hospitals, the others being divided among several specialities.

Number of Beds - The distribution of respondents in terms of bed size is as follows:

TABLE IV: Distribution of Respondents in Terms of Bed Size

	N	%		N	%
under 100	23	9.7	801-900	6	2.5
101-200	52	21.8	901-1000	11	4.6
201-300	41	17.2	1001-1100	3	1.3
301-400	39	16.4	1101-1200	1	.4
401-500	29	12.2	1201-1300	5	2.1
501-600	14	5.9	1301-1400	1	.4
601-700	5	2.1	1401-1500	-	-
701-800	3	1.3	over 1500	5	2.1

For ten hospitals data not available

The hospitals in the sample are considerably larger than the average American hospital.[1] We are dealing with hospitals predominantly in the upper half, and mostly in the upper quarter.

Budget - The mean budget among respondent hospitals is approximately eight million dollars.

Organization of Medical Equipment Maintenance and Repair - Respondents were asked about medical equipment inventory, maintenance and repair records, maintenance and repair management, and whether their hospitals have guidelines for maintenance and repair. The breakdown of responses is as follows:

1. The AHA directory's statistics show that American hospitals divide into quartiles as follows: 1st Q - under 45, 2nd Q - 49092, 3rd Q - 93-222, 4th Q - over 222. The respondents fall into these quartiles: 1st Q - 4 (1.7%), 2nd Q - 16 (6.7%), 3rd Q - 63 (26.5%), 4th Q - 155 (65.1%)

TABLE V: How Medical Equipment Repair and Maintenance is Organized

Is an equipment inventory kept?

Yes, centrally	126 (51.4%)
Yes, by dept.	60 (24.5%)
both	45 (18.4%)
not kept	14 (5.7%)

Are maintenance/repair records kept?

Yes, centrally	96 (39.7%)
Yes, by dept.	72 (29.8%)
both	27 (11.2%)
not kept	47 (19.4%)

How is medical equipment maintenance/repair managed?

centrally	111 (47%)
by dept.	112 (47.5%)
both	113 (5.5%)

Do you have guidelines specifying how maintenance/ repair should be handled?

yes	134 (57.8%)
no	98 (42.2%)

Responses on these four aspects of the organization of medical equipment maintenance and repair were analyzed to see if any typical configurations would emerge. For groupings of ten or more hospitals only four patterns emerged.

TABLE VI: Organization of Maintenance and Repair in Hospitals

No.of Hos.	Inventory	M/R Records	M/R Manage.	Guidelines
42	central	central	central	yes
20	dept.	dept.	dept.	dept.
14	central	dept.	dept.	no
13	both	central	central	central

Method of Performing Major Repairs - Hospitals were asked how major repair of their medical equipment is carried out (by hospital staff, by maintenance contract company, by medical

supply house, by the manufacturer) and asked to indicate whether they used each of these methods often, seldom, or never.[1] The frequency distribution is as follows (all percentages are based on row sums):

TABLE VII: How Frequently Repair Is Carried Out by Four Groups

Method	Often	Sometimes	Seldom	Total Resp.
by hosp. staff	78 (32%)	88 (36%)	78 (32%)	244
by main. cont.	81 (33%)	89 (37%)	74 (30%)	244
by supply house	25 (10%)	77 (31%)	143 (58%)	245
by manufacturer	86 (35%)	102 (42%)	57 (23%)	245

Scale of Percent of Repairs Done by Hospital Staff - With the data in the previous section, a rating system was used to determine the approximate percentage of major equipment maintenance/repair performed within a hospital by its own hospital staff.[2]

1. In analyzing the responses, it was assumed that if a hospital checked, for example, that it "sometimes" used its own staff, and "sometimes" the manufacturer, then it "seldom" used the other two methods - by maintenance contract company and supply house - even if "seldom" was not checked for these methods.

2. Responses were given weights: seldom = 0, sometimes = 1, often = 2. Then these scores for the four methods were added and the score assigned to "by hospital staff" divided by the total of units. For example, if a response were as follows:

Method	Often	Sometimes	Seldom
by hospital staff	✓(=2)		
by maintenance contract		✓(=1)	
by supply house			✓(=0)
by manufacturer			✓(=0)

The units total 3, 2 being assigned to hospital staff, and 1 to maintenance contract company. Thus 2, the score given to hospital staff, divided by 3 gives a percentage of 67% of major repairs done by the hospital's own personnel. Again, it was assumed that not checking one method while checking others is the same as a response of seldom and this was given a score of 0. In other words, the percentage arrived at in the example above would have been the same if "by supply house" and "by manufacturer" had been left blank rather than checked as "seldom" by the respondent. It is not presumed that this measure give the exact percent of repairs done internally, but that it gives a rough but reasonable measure and allows us to rank hospitals fairly reliably in terms of the percent of repairs done by resident technicians.

The distribution of respondents according to these ratings is as follows:

TABLE VIII: Percentage of Major Repairs Done By In-House Staff

APPROXIMATE % MAJOR REPAIRS DONE BY IN-HOUSE STAFF	NUMBER OF RESPONDENTS
0%	78 (32%)
1-10%	0 (0%)
11-20%	19 (8%)
21-30%	36 (15%)
31-40%	54 (22%)
41-50%	29 (12%)
51-60%	0 (0%)
61-70%	22 (9%)
71-80%	1 (0.4%)
81-90%	0 (0%)
91-100%	6 (2%)

Blanks - 3

The mean value for the above is 27.6%, indicating that the average hospital in the sample has slightly over one-quarter of its major repairs done by in-house staff. Almost a third of the hospitals do not claim to do any major repairs, since major repairs are bound to at some point require schematics or tools not available to hospital staff, not to mention the fact that outside servicemen are called in on warranties, which are attached to almost any new piece of medical equipment.

Organizational Change - The question was asked whether hospitals were planning any major change in the organization of medical equipment maintenance in the near future, and if so, whether such change would be in the direction of centralization or decentralization. One hundred and sixty-three (66.8%) indicated that no major change was planned; 74 (30.3%) indicated change in the direction of centralization; and only 6 (2.5%) indicated change towards decentralization. That one-third indicated plans for major organizational change shows considerable consciousness of a need for change in the maintenance and repair system for medical equipment.

Repair Technician Manpower - Respondents were asked whether they have in-house technicians who repair medical equipment, and if so, how many. One hundred and thirty-four (54.7%) stated that they have such technicians. The breakdown by

number of such technicians employed in a hospital is:[1]

TABLE IX: Number of Technicians Employed by Hospitals

# Technicians	Hospitals	%
0	111	45.3%
1	39	15.9%
2	44	18.0%
3	21	8.6%
4	9	3.7%
5 or more	21	8.6%

Plans to Hire BMET's - One of the questionnaire items was, "Do you anticipate hiring any [BMET's] in the next twelve months?" Of the 230 who answered this item, 55 (23.9%) said yes, 8 (3.5%) say maybe, and 167 (72.6%) said no.

Budget - Respondents were asked to provide budgetary data regarding both medical equipment maintenance/repair and purchasing new medical equipment.[2] Ninety-two percent of the respondents indicated that under 1.5% of the annual hospital budget was spent on maintenance and repair. (This reflects an expenditure of $60,000 or less, with the majority of hospitals spending under $20,000.) Close to 85% of the respondents mentioned that under 3.5% of the annual budget was spent on new medical equipment (reflecting expenditures under $150,000, with the majority under $100,000).

Hospitals were asked whether their budgets for new medical equipment are fixed or fluctuating. Of the 215 who responded to this question only three marked fixed, the rest fluctuating. Of the 181 who indicated the direction of fluctuation, 165 note general increase in the annual budget for new medical equipment.

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1. The technicians referred to by respondents may not be BMET's - they may be lab technicians, X-ray technicians, etc. who do some repair work, but do not spend 50% or more of their time on repairs.

2. On these questions about one hundred respondents did not give figures for new equipment budget - slightly more did not give them for maintenance/repair. It is possible that those supplying figures are above average within the sample in terms of money spent in these areas.

Training Programs - Hospitals were asked whether they are associated with educational institutions in cooperative or work-study training programs for medical equipment technicians and whether they would be interested in such programs. Only 19 (7.7%) stated that they currently participate in such programs, but 129 (52.4%) of the respondents said that although currently not participating they would be interested. Seventy-six (30.9%) indicated that they would not be interested, and 22 (8.9%) checked "no" for current participation, but did not indicate whether they would be interested or not.

PART II. COMPARATIVE DATA

A. Characteristics Related to the Number of BMET's in a Hospital

As expected, it was found that larger hospitals are not only more likely to have technicians performing repair work, but they are also more likely to have more of them. Hospitals in the sample were divided into three categories according to the number of beds (small - under 201, medium = 201-400, large = over 400). Hospital size correlates with the number of technicians repairing medical equipment with a coefficient of .461 at a level of significance beyond .001. We find that hospitals with three or more repair technicians are especially likely to be in the large hospital category. Likewise, it was found that the larger the hospital budget allocated to medical equipment, the more likely it is that a hospital has such repair technicians. No conclusive evidence was found to indicate whether or not hospitals that repair a large percentage of their own medical equipment are more likely to have lower budgets for medical equipment repair or higher budgets for new medical equipment. (Both these points merit further study.)

Region - The data was examined for regional variations in the employment of technicians performing repair. Although the small number of cases makes one hesitant to generalize, there was no pattern of strong regional variations. The distribution among regions is remarkably similar. We might expect certain regions to be the loci of the development of a BMET role within hospitals,but such an expectation is not borne out in the data.

Type of Hospital - Those indicating that they are teaching or research hospitals tend to do more of their own repair

work.[1] Specialty hospitals tend to do less of their own repair work than do general hospitals; 69% do almost none as opposed to 42% of general hospitals - and those specialty hospitals who have technicians performing repairs have fewer of them. Since most specialty hospitals - such as psychiatric or rehabilitation hospitals - do not require as much medical instrumentation as general hospitals, this in understandable. (There are exceptions, of course, such as specialty hospitals engaged in cardiac care.)

The data was examined to see how having or not having BMET's is related to the degree of centralized organization of medical equipment maintenance/repair.[2]

The sample may be divided into two groups; those above average in degree of centralization, and those below average - the former having a tendency to have more technicians performing repairs. The correlation is not very strong (.302) or significant (.104). It would be incorrect to make conclusions on the basis of this data, but a plausible explanation is that there are several quite different modes of central control. Two modes are probably most common. The first is to have a unit of technicians which does maintenance/repair for the hospital as a whole rather than having such technicians under the aegis of hospital departments. The second mode is for

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1. Teaching or research hospitals are both associated with a positive variance of 35% in a scale of the number of BMET's running 0,1,2,3,4,5+, the correlations being significant at .001.

2. From responses to questions discussed earlier in this report about medical equipment inventory, maintenance/repair records, M/R management, and hospital guidelines, a scale was constructed for the degree of central control in hospitals. Values were assigned:

Inventory (cent.= 1, both cent.& by dept.= 2, dept.= 3, not kept = 4)
M/R records (cent.= 1, both = 2, dept.=3, not kept = 4)
Management (cent.= 1, both = 2.5, dept.= 4)
Guidelines (yes = 1, no = 4)

Values on the index ranged from 4 to 16 in decreasing degree of centralization. The index was then categorized as follows:

4 - 5.5 = High - 56 (25.2%)
6 - 8.5 = Over Average - 53 (23.9%)
9 - 12.5 = Below Average - 64 (28.8%)
13 or over = Low - 49 (22.1%)

the administrative or business office to arrange maintenance/repair with outside agencies such as maintenance companies, medical supply houses, or manufacturers.

B. Characteristics Related to Bed Size of Hospitals

Bed size is one of the major variables thought to affect medical equipment and its maintenance/repair. Cross-tabulations were run to see the relation of bed size to other variables. [1]

1) Plans to Hire - Larger hospitals tend to have more repair technicians and are more likely to have plans to hire additional repair technicians. (Those who do not have repair technicians but plan to hire them do not quite fit the pattern, but there are only ten of these.) The teaching, research, and general hospitals are larger than specialty hospitals, which probably explains the tendency for them to have more BMET's, as well as to plan to hire more BMET's.

2) Centralization - Cross-tabulations showed little or no relationship between bed size and degree of centralization of medical equipment maintenance/repair. Within all four categories in terms of centralization - decentralization, roughly equal numbers of hospitals fell into the small, medium and large bed size categories.

3) Budget - When bed size was compared with the percentage of hospital budget devoted to medical equipment maintenance/repair, our data did not show that larger hospitals devote a higher percentage of their budget to medical equipment maintenance/repair or to new medical equipment; if anything, a slightly inverse relationship was shown.

C. Characteristics Related to Percentage of Repairs Done Internally by Hospital Staff

One of the most important variables affecting the BMET situation is the proportion of major repairs done by hospital staff.

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1. As indicated before, hospitals were divided into three roughly equal groups: small - under 201, medium - 201-400, large - over 400 beds. Also previously noted was a correlation coefficient of .461 between the bed size category and the number of BMET's.

1) Bed Size - The data shows a significant correlation between number of beds and the percent of repairs done by hospital staff. The important differences show up between hospitals in the low category on the one hand, and those medium and high on the other. The data conforms strongly to the thesis that there is a marginal cutting point of hospital size (approximately 200 beds) beyond which it becomes feasible for a hospital to employ personnel who do major repairs, as opposed to employing outside agencies. (This point deserves further study and confirmation.)

2) Budget - A pattern emerges from our data regarding the relation of the percentage of repairs done internally and budget figures. The percentage figures for medical equipment maintenance/repair as well as for new equipment do not correlate significantly with the percentage of repairs done internally, but there is a solid correlation between absolute amounts spent and the percentage of internal repairs, the proviso being that beyond a certain level of expenditures the percentage of repairs done internally does not increase very much.

CONCLUSION

The primary aim of this survey was to find out what kind of hospitals might employ BMET's. In summary, the following was found:

1. The smaller the hospital size the less likely a hospital is to have BMET's. Hospitals under 200 beds rarely have BMET's. Larger hospitals tend to have more BMET's.

2. The larger the total budget (in terms of dollars, not percent) spent on medical equipment, the more likely a hospital is to have BMET's.

3. Absolute size (not percentage) of budget for new medical equipment varies directly with whether or not a hospital employs BMET's.

4. The proportion of repairs done internally varies directly with the number of BMET's a hospital has.

5. Teaching and research hospitals are more likely to have BMET's, or at least do their own repair work.

6. The more centralized the organization of medical equipment maintenance/repair, the more likely it is that a hospital employs BMET's.

7

Relationships were probed but not found to correlate to any significant degree with geographical region and with the percentage of the budget spent on maintenance/repair of medical equipment. However, the evidence that these characteristics are not substantially related to the employment of BMET's is much less conclusive than the evidence establishing that certain characteristics are positively related to BMET employment, the latter being based on strong and highly significant correlations.

APPENDIX F. REGIONAL DIFFERENCES

APPENDIX F

REGIONAL DIFFERENCES

Interviewers returned from their interviewing with a variety of impressions about respondents' attitudes toward the BMET and the biomedical field which seemed to reflect geographical differences. We therefore decided it would be interesting to look at our hard data on the basis of geographical regions. We divided our 24 sample cities into seven geographical regions and looked at regional responses to several questions which we felt might show interesting statistical differences by region. In fact, very few differences were found. The regional groupings are:

TABLE X
NUMBERS OF HOSPITALS AND COMPANIES BY REGION

	Hospitals	Companies	Total
North East - Boston, New Jersey, New York, and Philadelphia	32	4	36
North Mid-west - Chicago, Milwaukee, Minneapolis/St. Paul	26	9	35
East Mid-west - Cleveland, Detroit and Pittsburgh	18	14	32
Mid-West - Indianapolis, Kansas City, and St. Louis	21	12	33
South East - Atlanta, Baltimore, Miami, Washington, D. C.	22	13	35
South West - Dallas, Houston, and New Orleans	19	13	32
Far West - Denver, Los Angeles, San Francisco, and Seattle	41	26	67

Each respondent was asked whether or not his institution had a training program for BMET's. Companies are more likely

than are hospitals to have BMET training programs, and thus there is an understandable correlation between a high percentage of BMET training programs in a given region and a high percentage of companies among the interviews in that region. We had felt that perhaps certain regions of the country would be more likely to have training programs than others. However, we found that any differences in numbers of training programs in different regions is a function of the numbers of companies interviewed in that region, rather than a function of any real regional differences.

Each respondent was asked to approximate the percentage of time his technician spends on a series of tasks. There are no apparent significant differences in the percent of time spent on these various tasks for each region -- in all regions technicians spend the greatest percentage of their time on preventive maintenance and major repairs with the rest of their time divided among administration, operation, training, modification and design of medical equipment, and general hospital maintenance.[1]

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1. A slightly higher percent of time spent on modification and design in the South West might be explained by the high number of research institutes and companies interviewed there. Slightly higher percentages of time spent on general maintenance in the North East might be explained by the greater number of Type I BMET's interviewed there.

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TABLE XI

PERCENTAGE OF BMET'S TIME SPENT ON FUNCTIONS BY REGION

	Administration	Operating Equip.	PM/ Calibration	Major Repairs	Instruc. Others	Modification/ Design	Training	General Maintenance
North East	9%	7	24	22	7	7	6	18
North Mid West	4%	5	21	40	6	7	6	11
East Mid West	6%	5	14	47	8	9	5	6
Mid West	7%	7	17	44	6	6	5	8
South East	9%	2	17	43	6	8	5	10
South West	8%	3	16	42	6	16	5	4
Far West	7%	1	19	46	5	7	4	11

Each respondent was asked to approximate the percentage of time his technician spends on various components of equipment. Electronics, mechanics and electromechanics occupy over 75% of the total technician's time in each region.[1]

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1. There is an interesting increase in the importance of electromechanics over mechanics in the East Mid West, possibly explained by the figures for Cleveland - 36% electromechanics and 9% mechanics as compared to the national averages of 19% and 16% respectively.

TABLE XII

PERCENTAGE OF BMET'S TIME SPENT ON COMPONENT BY REGION

	Component							
	Electronics	Optics	Mechanics	Hydraulics	Electro-Mechanics	Electro-Optics	Pneumatics	Other
North East	36%	2	25	3	18	3	5	8
North Mid West	55%	3	18	2	14	3	2	3
East Mid West	55%	1	12	2	25	1	1	3
Mid West	33%	5	26	5	18	2	9	2
South East	53%	3	7	2	12	4	2	7
South West	51%	4	13	4	13	6	7	2
Far West	51%	2	22	3	16	2	2	2

We had felt that the number of grades (levels) of technician found in an institution and the technician's occupational mobility might vary by region. However, there are seemingly no real differences by region in the number of grades of technicians found in each institution, or in the percentage of those who can move from technician to engineer status.

We had also felt that the number of technicians employed in any institution might vary by region. The only significant difference in the numbers of BMET's found per department is in the North East region, which had slightly higher numbers of BMET's per department.[1]

We ascertained what percentage of technicians in an institution came to the job with training in biomedical equipment. This percentage differs significantly from region to region. The North East (46%) and the Far West (45%) are much higher than the other regions which range from 23% to 25%. This might be explained by the fact that the East and West coasts are thought by some to be technologically more advanced, more research-oriented, (companies and educational institutions have been established in those regions longer and are more plentiful) and these areas tend to attract, as well as produce, more highly trained personnel than other areas.

We were most interested in looking at the salary scales in the seven regions as we felt this might produce differences. The only divergence from the norm was found in the North Mid West and the South East which show slightly higher maximum salary ranges than the other regions.

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1. This can be explained by the unusually large numbers of BMET's per department in the New Jersey - New York area.

TABLE XIII

BMET SALARY LEVELS BY REGION

	Salary		
	Minimum	Medium	Maximum
North East	$6-7000	8-9000	10-11000
North Mid West	$7-8000	7-8000	11-12000
East Mid West	$6-7000	8-9000	10-11000
Mid West	$6-7000	7-8000	10-11000
South East	$6-7000	8-9000	11-12000
South West	$6-7000	7-8000	10-11000
Far West	$7-8000	8-9000	10-11000

Because interviewers had picked up differences in attitudes toward the BMET, BMET training programs, and to our survey, depending upon what area of the country they were interviewing in, we expected to find substantial statistical differences in answers to a number of key questions. However, differences among regions are not significant[1] with the exception of numbers of BMET's who are employed with previous biomedical equipment training. This suggests that in large part the biomedical equipment field remains independent of geographical and regional factors.

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1. Significant differences would have been statistics differing by 10% or more.

APPENDIX G. DIFFERENCES BETWEEN HOSPITALS AND COMPANIES

APPENDIX G

DIFFERENCES BETWEEN HOSPITALS AND COMPANIES

There are a number of interesting differences between hospitals and companies who employ BMET's, including the types of technicians whom they seek to employ or are willing to employ, the kinds of equipment which their BMET's work on, the type of training which they offer, and the career potentials and status available in each institution.

Most BMET's in companies (TABLE XIV) were specialized, , working on a limited range of equipment and more often performing major repairs than minor repairs. BMET's in hospitals are more likely to be generalized, working on a wider range of equipment and spending somewhat less time on major repairs, not necessarily because they do not have the skills to perform major repairs, but because they may not have the necessary tools, schematics, or parts, or because it is more economical for the hospital to send out some equipment for major repairs.

TABLE XIV

DISTRIBUTION OF BMET TYPES BY INSTITUTION

	Companies (98)	Hospitals (179)	Total
Janitorial	0%	19%	13%
Generalized	20%	46%	37%
Specialized	80%	35%	50%

In hospitals we found a greater range of technician skill levels, from the janitorial type who spends a good proportion of his time repairing non-medical equipment, to the highly skilled BMET who not only repairs equipment competently, but also modifies or builds equipment.

In comparing the backgrounds of hospital employed BMET's

with those of company employed BMET's we found very little difference in formal educational and work experience backgrounds.

TABLE XV

EDUCATIONAL BACKGROUNDS OF BMET'S BY INSTITUTION

	Companies	Hospitals
% not high school graduates	5	5
% high school graduates	29	29
% post-high school education	66	66
	100%	100%

TABLE XVI

AREA IN WHICH BMET'S WERE WORKING BEFORE HIRED BY INSTITUTION

	Companies	Hospitals
% biomedical equipment	15	23
% electronics	57	41
% mechanics	7	11
% optics	1	less than 1
% electro-optics	1	1
% electro-mechanics	3	3
% other	16	21
	100%	100%

These data indicate that both companies and hospitals tend to hire technicians with some post-high school training. Both hire more technicians with an electronics background.

When asked what percent of the technicians did not need on-the-job training, hospital respondents indicated that approximately 39% of the BMET's whom they hired were already

trained, compared to 21% of company hired BMET's. Based on our experience, we might guess that because companies have a commitment to training BMET's they are more willing to hire someone with a general technical background and then train him to repair their specific equipment. In contrast, hospitals often look for someone who is already trained because they usually have no commitment to extensive training at this level.

BMET's employed in companies and hospitals seem to spend their time performing similar functions, with two exceptions. In examining our equipment list, we found that BMET's in companies are more involved in the installation of new equipment. And, as seen in TABLE XVII, hospital BMET's spend less time repairing medical equipment, and, as expected, more time repairing non-medical equipment.

TABLE XVII

PERCENTAGE OF TIME SPENT ON BMET FUNCTIONS BY INSTITUTION

Function	Companies	Hospitals
Administrative	9%	6%
Operating equipment	2%	4%
Preventive maintenance/calibration	18%	18%
Minor/major repairs	50%	36%
Instructing others	6%	6%
Modifying/designing/building	4%	11%
In training (upgrading)	4%	5%
General hospital maintenance (non-medical equipment)	2%	14%
	100%	100%

We found that differences in the pieces of medical equipment the BMET's worked on depended on whether they were employed by companies or hospitals. The BMET employed in hospitals and research institutions works on a wide range of equipment which is varied in theory, application, and structure. The BMET employed by industry is usually limited to those specific items falling within the company's product line. The majority of BMET's, however, regardless of place of employment,

seem to require an educational experience in cardiovascular intensive care equipment, as indicated by Plates 14 and 15. We emphasize, however, that the distribution of equipment which industry-employed BMET's work on is influenced by the companies whom we chose to interview, and may or may not be a representative picture of the biomedical equipment field.

Companies and hospitals also expect different entry skill levels and job qualifications when hiring technicians. It would seem from the charts presented in the main text in the chapter on Job Qualifications, that hospitals are somewhat more likely to be seeking experienced, competent BMET's than companies. (Sixty-four percent of our company respondents said that they did not expect a newly hired technician to be familiar with biomedical equipment; fifty-five percent of hospital respondents said they did.) Companies also stress the importance of the potential employee's character and personality - neat appearance, pleasant personality, ability to communicate effectively, initiative. Several respondents in companies said quite firmly that they would not hire a BMET, regardless of his technical competence, unless he could "represent the company" well. The BMET in a company, then, must be a salesman and a public relations man, in addition to being a serviceman.

In the chapter on BMET training we described the differences between companies' and hospitals' training facilities and methods. While both rely heavily on informal on-the-job training for their BMET's, more companies than hospitals have formal training programs. Since companies often have some commitment for methodical training and hospitals seldom do, it is understandable that hospitals look for BMET's with experience.

There are other interesting contrasts, too, which we have discussed in more detail in the main text. There appears to be a more defined (although not necessarily accessible) career ladder in companies than in hospitals (see chapter in main text on careers). The BMET may move from trainee to senior technician to engineer much more easily in a company than in a hospital. Companies also tend to have larger BMET departments than most hospitals.

The maximum salary offered by companies is greater than that offered by hospitals, but our analysis of the minimum and average salaries offered by both shows little difference. In fact, the mean salary in hospitals was slightly higher than in industry. However, companies are in a position to, and do, provide the BMET with a variety of fringe benefits sss which are not available to the hospital-employed BMET.

TABLE XVIII

PERCENTAGE OF RESPONDENTS GIVING REASONS FOR LEAVING JOB BY INSTITUTION[1]

Reason	Co.(55)	Hosp,(75)	Whole Samp.
Just wanted a change - of job, city, etc.	9%	13%	12%
Lack of opportunity to advance	22%	15%	18%
Inadequate salary	21%	44%	34%
Lack of interest in work	13%	7%	9%
Lack of competence to do work	43%	16%	28%
Interpersonal conflicts	14%	8%	11%
Military service	7%	3%	5%
Return to school	13%	15%	14%
Other (generally personal reasons)	23%	34%	20%
Don't know	2%	10%	6%

1. These responses may not reflect the reasons why BMET thought he left as we did not interview him, but the colleagues he left behind.

Respondents were asked why they felt BMET's who were no longer in their employ or in the biomedical equipment field had left. In hospitals respondents most often mentioned inadequate salary as the reason why other BMET's left. In companies lack of competence was the most often mentioned reason for leaving. This does not necessarily indicate that hospital BMET's are more competent than company BMET's; rather, it may indicate the lack of standards in hospitals by which to evaluate the BMET's performance, as well as the lack of qualified persons to make such an evaluation. (The larger companies frequently have probationary periods, during which the trainee is closely supervised. If his performance is unsatisfactory, he will be asked to leave.)

It is unfortunate that we have no hard data on where the BMET's went when they left the institution or the field, in addition to why they left. Before analyzing our data, we had the impression that BMET's left hospitals for employment in large companies, and that this posed a very real problem for hospitals. However, when we consider that 39% of the BMET's hired in hospitals were already trained, and at least 30% of those were trained in industry, it appears that there is some movement in the other direction as well. A few interesting case studies may illustrate some of the reasons that BMET's leave companies for hospitals.

Frank had been working as a service technician for an X-ray manufacturer. He left to accept a similar position in a hospital, where he still spends most of his time repairing X-ray equipment, but also works closely with the Chief Radiologist in planning seminars for the X-ray technicians, advising him on what X-ray equipment to purchase or lease, and so on. He sets his own hours, and works completely on his own. He explained that he left the X-ray company because he wanted the opportunity to be his own boss and because he felt that he knew more about X-ray equipment repair than his supervisor, who was one of the "old-timers" in the company.

Adam had held a fairly high position in service in a manufacturing company. He left to accept a lower-salaried position in a university medical center in another state where he organized his own Biomedical Engineering Department. He was free to rearrange the medical equipment maintenance system, to hire his own staff, and so on. He explained that he was frustrated with "the rat-race in industry," and now enjoyed the "more pleasant atmosphere at the hospital."

Robert had been employed in a supply house that dealt primarily with monitoring equipment. He now works in a research institute, spending most of his time designing, modifying, and building equipment. He works closely with the doctors and engineers, assisting them in planning for the expansion of the research unit. He explained that he had become tired "of an endless stream of repairs at countless hospitals. Now, I feel that this unit is my 'baby'."

We do not assume that all BMET's, or even the majority, who leave companies for hospitals are cases such as the ones described above. For example, the BMET's who leave companies because of lack of competence may seek employment in hospitals. In addition, one respondent saw a trend developing in which BMET's were leaving industry for hospitals because of discontent "with being on the road so much." At least one respondent saw a cyclical pattern:

"We see little indication of our BMET's leaving to join a hospital. Of the limited number who have done so, several have returned stating that they were not utilizing their know-how at the hospital - they were called upon to do janitorial repair work."

We suspect that a highly-skilled BMET, possibly one of the specialists in our hospital sample, would, in fact, obtain considerable satisfaction from being his own boss, from working closely with professionals, and being afforded their respect, and from sensing his importance in the smooth-running, planning, and design of sophisticated medical units. Some BMET's, however, are victims of hospital ignorance - underutilized, under-paid, and under-equipped with the necessary tools and work space; such BMET's are likely to move to companies because the company can provide him with a certain recognition and status which his hospital is apparently unable or unwilling to do.

We are not negating the importance of salary as a reason for changing jobs. Certainly, experienced BMET's who have reached the maximum salary in their hospital and can obtain a higher salary at a large manufacturing company may consider the transfer. However, we suspect that salary alone does not explain why BMET's move from employment in one type of institution to another. While companies can offer the BMET a clear role, clear supervision, and a defined status, hospitals can also offer him the opportunity to be independent and creative. Hospitals can add other parameters to his work such as developing, designing, modifying, and teaching. They also can give him the responsibility for making decisions which affect

the total medical equipment maintenance system in the hospital. And they can give him the opportunity to work closely with medical professionals in a consistent and meaningful way. This requires a conscious effort on the part of the hospital, which presupposes that the administrator, the doctors, and the engineers understand what a BMET can and should do. In other words, the highly skilled BMET who sees himself as a professional must be recognized as such by a hospital if that hospital hopes to hire him - or more importantly, to retain him.

APPENDIX H. ALLIED HEALTH ACT

APPENDIX H

THE ALLIED HEALTH ACT

The Allied Health Professions Personnel Training Act of 1966 was enacted by Congress to implement the education of persons for health and technical occupations that are essential to the growth of efficient health care systems in this country. It was intended to increase the opportunities for and the quality of training programs, both two and four year, for the Allied Health Professions.[1].

The Act authorized four types of grants in aid to "training centers for allied health professions": (1) for construction or renovation of teaching facilities; (2) for improvement of the quality of curriculum at existing programs; (3) for traineeships for advanced training of Allied Health personnel for teaching and supervisory jobs; and (4) for development, demonstration, or evaluation of curriculum for training new types of health technologists. These grants are available to junior colleges, colleges, and universities whose programs in health professions include at least twenty persons and which either include or are affiliated with a teaching hospital. The necessity of facilities for on-the-job training was considered very important both for good training and to attract and hold students in the fields.

Because of the numbers of programs and areas which could be eligible for grants, and because of the limited funds available, priority for assistance was given to those occupations most directly related to patient care and those for which shortages were most fully documented. A list of Allied Health

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1. Extensive information on the Act and its implementation are contained in "A Report to the President and the Congress: The Allied Health Professions Personnel Training Act of 1966 as Amended," U. S. Department of Health, Education, and Welfare, National Institutes of Health, Bureau of Health Professions Education and Manpower Training, Division of Allied Health Manpower, Bethesda, Maryland 20014. More information can be obtained by calling that office.

Disciplines were developed which included nine courses at the baccalaureate level and twelve courses at the associate degree level. The biomedical equipment technician is not included on this list and therefore, so far is ineligible for grants under the first three categories.[2]

The Developmental Grant provides funds for new programs for health occupations not on the list of Allied Health disciplines. Its purpose was to provide funds for the "development of curriculum for training new types of Allied Health Personnel" as well as the development of innovative approaches to existing training programs. However, so far, BMET programs have not received funding under this grant because there are too many BMET training programs currently in existence. Currently no funds are available to establish newly developed curricula (outside the list of Allied Health Disciplines) at institutions without them. There is a possibility that two bills presently before Congress[3] will provide special projects grants under which BMET training programs might be supported.

There is recognition of the need for growth in the number of BMET's, but funding is so limited that it can barely support the existing Allied Health Profession programs to which they are committed. Although the 1966 Bill expires as of July, 1970, there is no reason at present to believe that, if Congress re-approves it, there will be any changes in the amount of funding available for projects other than those already on the list, or that any new occupation will be added to the list of Allied Health Disciplines.

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2. We know of at least one community college which unsuccessfully attempted to get funding for a two-year BMET program under this Act.

3. The bills will be acted on sometime in July, 1970.

APPENDIX I. SAFETY LEGISLATION

APPENDIX I

UPDATING ON SAFETY LEGISLATION[1]

In recent years there has been a great increase in the number of different types of biomedical instruments, as well as an increase in the number of manufacturers involved in the biomedical instrument field. Accompanying these developments is a growing concern about how to regulate their manufacture, their standardization, and their distribution, and how to assess and to ensure their efficiency and safety, especially in light of startling statistics about accidental electrocution in hospitals.[2] Often there is no individual on the hospital staff who can carefully evaluate the need for and the quality of sophisticated medical equipment, and many hospital personnel, including physicians, are not properly aware of the potential hazards in using this equipment on patients. The fact that there have been instances of instrument failure which have resulted in patient injuries and fatalities clearly indicates the need for some kind of effective control over the biomedical instrument field.

At present the only federal legislation affecting biomedical equipment is that of the Food and Drug Administration (since recent court decisions--Difco and AMP--established a basis for treating conventional medical devices as drugs). This means that regulation is now largely a matter of after-the-fact enforcement in which the government must show that a device is dangerous or misbranded. Many professionals in the field, however, feel that new legislation is mandatory. At the National Conference on Medical Devices held in September, 1969, the following kinds of recommendations were made:

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1. For a bibliography of articles on safety in hospitals, refer to Appendix Q.

2. Most of the information used in this Appendix concerning equipment safety problems and recommendations was taken from "Excerpts and Summary of a National Conference on Medical Devices," Medical Research Engineering, December 1969.

1. The National Academies of Science and Engineering [should] be requested to prepare new definitions of medical devices, articles and drugs, together with a classification of biomedical devices.

2. New legislation should be prepared, based on these new definitions of biomedical devices, articles and drugs.

3. Such legislation should include requirements for:

   a. good manufacturing practices by producers of medical devices

   b. factory inspection

   c. registration of manufacturing facilities and distribution centers

   d. filing of appropriate product complaints with enforcement and surveillance agencies

   e. recall authority invested in enforcement agency

   f. notification to enforcement and surveillance agencies of medical devices now on the market and marketing for the future.

It is the consensus of this Task Force that:

1. enforcement is the proper function of government

2. standards-setting is the proper function of the professionals and industry. The government should approve or certify standards-setting procedures

3. surveillance is the proper function of all above parties.

In addition to making recommendations about developing legislation on biomedical equipment, the Task Force at the National Conference made a number of other interesting recommendations. In discussing standards and standardization, for example, they recommended that industry "supply instructions for critical testing of medical devices when possible, provide information on composition of all prosthetic devices implanted in the body, and supply wiring diagrams, testing circuits, etc., for all electrical and electronic devices." They further suggested that manufacturers must be prepared to train and retrain the medical and technical personnel who

operate and maintain the equipment.

The Task Force emphasized that, while regulatory measures were necessary, these measures should be sufficiently flexible so as not to impede progress in the development of medical instruments. In particular, they pointed out that small companies would have difficulty surviving if complex or unduly prolonged review and evaluation procedures were instituted which kept a new product off the market for a great length of time while it was being tested and evaluated. Furthermore, small companies would not be able to afford a sizeable in-house staff who could do extensive testing of a new instrument. In one sense, however, small companies would benefit from the institution of regulatory measures. If a product had to receive a "seal of approval" from some agency before it could be marketed, hospitals might feel more comfortable about shopping around in both large and small companies before purchasing new medical equipment.

In addition to some kind of regulatory legislation that will ensure standardization, safety, and efficacy of medical instruments, there is another whole area that must also be developed: education and communication. Along these lines, the Task Force recommends the following:

1. that courses in the safe and effective use of biomedical instrumentation should be included in the curriculum of all health professional schools;

2. that teaching hospitals should offer to biomedical engineers an educational program analogous to medical internship or residency;

3. that all hospital technicians who operate, maintain, or repair biomedical instrumentation should show evidence of proficiency which meets established standards, either by examination or certificate of training;

4. that continuing education regarding biomedical equipment should be a part of hospital training programs;

5. that a central repository of information, training and research programs, terminology, bibliographies, and applicable legislative and judicial decisions should be established;

6. that in addition to disseminating <u>all</u> pertinent information and instructions to users of their equipment, manufacturers have an obligation to collect and disseminate reports of adverse effects of their instruments;

7. that closer communication between physicians and engineers should be encouraged by joint educational efforts;

8. that hospital administrators obtain advice from knowledgeable bioengineering and/or medical specialists other than the vendor on the relative merits of competitive devices. The Joint Commission on Hospital Accreditation is urged to incorporate in its standards a requirement that expert advice concerning safe use and preventive maintenance of all biomedical devices be available at all times;

Clearly, the BMET can play an important role in the issues of equipment safety in the hospitals. Properly trained, he can be responsible for preventive maintenance, for testing instruments before they are attached to patients, for instructing nurses, technicians, and physicians in the safe use of equipment, and for assisting the administration in making decisions concerning equipment maintenance and purchasing.

Most hospitals require compliance with some kind of local or in-house safety code, but few of these codes cover the safety factors which should be considered in using medical equipment, particularly electrical equipment which is attached to or implanted in patients. Hospitals are gradually realizing the need for such equipment safety codes, however. A potentially invaluable function of BMET's in hospitals, therefore, might be to implement or enforce instrumentation and electrical safety regulations.

APPENDIX J. SAMPLE JOB DESCRIPTIONS

APPENDIX J

SAMPLE JOB DESCRIPTIONS

Following are typical job descriptions for the position of biomedical equipment service technician in three hospitals and one company. They were copied directly from sheets given to interviewers by the respondents at these institutions.

Harris County Hospital District, Houston

Position - Assistant Medical Equipment Repairman

Job Summary

To perform minor repairs, calibration, installation, and maintenance on all types of medical equipment; and to assist the medical equipment repairman in major repairs. To handle work orders, order spare parts, and check parts received against shipping invoices.

Performance Requirements

Responsible for: Minor repairs, calibration, installation, and maintenance on all types and brands of medical equipment. For ordering parts when needed to repair equipment and parts for general shop use. Must check parts received against shipping invoices. Must be able to perform duties in a neat, efficient, and safe manner.

Physical Demands: Require considerable walking, working in tight places, working under stress in operating room conditions with equipment attached to patients, and lifting heavy objects.

Special Demands: Must be able to use meters and oscilloscope to check electrical and electronic equipment.

Qualifications

Education: Should have a high school education or equivalent, and specialized education in electric or electronic fields. Prefer graduate of Medical Equipment Maintenance School in Armed Services.

Training & Experience: Should have some experience in electronic equipment repair with part of it in the medical equipment field.

Employment Variables

Professional Affiliations: None

Working Environment

Work area is a well lighted, air conditioned shop with a work bench and tools furnished. Many jobs must be performed in various departments of the hospital. Some jobs require the handling of greasy and dirty equipment.

Job Relationship

Source of Workers: Electronics field with preference to Armed Service Medical Equipment Maintenance personnel
Promotion from: Job entry.
Promotion to: Medical Equipment Repairman, or Chief, Medical Repair Department.
Responsible to or supervised by: Medical Equipment Repairman, and Chief, Medical Equipment Department.
Workers Supervised: None
Interrelationship: Should be able to work around and with professional people (doctors, nurses, and engineers). Also able to perform tasks around patients and the public.

Picker X-Ray, Los Angeles

Job Description - Applications Engineer

A. Basic Function (area assigned, working supervisor)

1. Technical Consultant to service personnel under his direct supervision.
2. Assists Service Manager in supervision of General Field Service Operations.
3. Performs control during equipment installations.
4. Performs final check-out of installations.
5. Technical consultant to sales on installation.
6. Performs demonstration of equipment to salesmen and customer.

B. Scope of Responsibility

1. Works under general direction of Service Manager
2. Assumes responsibility for service personnel.
3. Assumes responsibility for satisfactory performance of equipment.
4. Technically consults with management for equipment revision to achieve satisfactory performance and/or upgrade equipment.
5. Assumes responsibility for all service work performed by group to which he is assigned.

C. Specific Duties

1. Reviews all equipment orders submitted by salesmen for which he is responsible to ascertain installation requirements.
2. Submits to salesmen any special labor or engineering costs.
3. Submits to planning department any special requirements to accommodate installation.
4. Coordinate all installation work being done by Picker personnel.
5. Acts as consultant to other vendors in order to coordinate pre-installation work.
6. Performs liaison functions with all equipment suppliers to assure engineering specifications are met in accordance with sales orders.
7. Performs final check-out of equipment upon installation completion.
8. Trains customer and sales personnel on operation of newly installed equipment.

9. Performs follow-up on performance of newly installed equipment to assure no unusual future service problem.
10. Reports on installation completions, satisfactory performance, and unusual service requirements.
11. Performs analysis of service work by assigned service personnel, identifies sources of troubles, recommends remedial action by reports to service manager and/or manufacturer of supplied equipment.
12. Performs duties of instructor in the training of service personnel.

Methodist Hospital, Indianapolis November 4, 1966

Job Description

JOB TITLE: Scientific Instrument Technician

DEPARTMENT: Physical Plant Staff and Engineering

JOB SUMMARY: Assists in repairing, testing, designing and constructing biotechnical and electronic equipment and systems.

WORK DONE: 1. Under the direction of the Chief Electronics Engineer, assists in maintaining biotechnical and electronic equipment and systems and performs the following tasks related thereto:

a. Repairs and calibrates biotechnical equipment (E. E.G. machine, diagnostic equipment, pace-makers, etc.) and systems.

b. Repairs and calibrates electronic equipment (communication devices, telemetry systems, etc.)

c. Performs scheduled preventive maintenance on biotechnical and electronic equipment.

d. Makes changes in existing equipment from modification/design blueprints.

e. Tests equipment for operational functions.

f. Maintains test equipment in state of good repair.

g. Installs biotechnical and electronic systems.

2. Keeps the electronic division workshop in a state of acceptable organization and cleanliness at all times.

3. Maintains appropriate records of repair and maintenance.

4. Performs any other duties that may be assigned.

JOB REQUIREMENTS:

Experience: None, however, must have potential to learn progressive technical knowledge.
Education: Satisfactory completion of a recognized electronic technical course.

Job Knowledge: Must have a functional understanding of the principles of electricity and know the various component systems of the hospital. Must know the functions of a variety of biotechnical and electronic equipment and systems. Must know how to repair, calibrate and test biotechnical and electronic equipment and systems. Must know how to use hand and machine tools and testing equipment used in work. Must know how to read blueprints and schematics.
Effect of Errors: Failure to repair and calibrate equipment properly would cause loss of time and money. Improper repair of equipment could lead to death. Failure to use tools and materials carefully would increase inventory costs.
Supervision: Supervises no one. Is directly responsible to the Chief Electronics Engineer.
Contacts: Has frequent contact with technicians, physicians, and department heads in the performance of duties.
Mental Effort: Must be extremely careful when assembling equipment. Frequently works against a prescribed deadline in repairing in-service equipment.
Physical Effort: Spends a considerable amount of time working at a repair bench at a single piece of equipment. Works in a variable pattern.
Surroundings: Spends considerable time in a workshop that is well-lighted and air-conditioned. Occasionally works around patients when repairing in-service equipment.
Hazards: Works with a variety of hand and power tools and hot irons. Most work involves electric circuitry. Occasionally exposed to undiagnosed disease when working around patients.

Stanford Medical Center January 7, 1969

Job Description - MEDICAL ELECTRONICS TECHNICIAN

Function of Job: To clean, maintain, and perform simple modifications on all Medical Center owned electronic equipment including CCTV, Radio Paging, patient monitoring, diagnostic and laboratory analytical systems. To maintain records of all service work performed and modifications made.

Minimum Qualifications: Must have a high school diploma indicating graduation in top one-third of the class. Must have at least one year of electronics training in a junior college. Must have at least two years' experience in electronic equipment construction and calibration techniques. Must be proficient in reading schematic diagrams and in the use of standard test equipment such as Oscilloscopes, Multi-Meters, VT VM's, Bridges, and similar items. Some experience with audio, CCTV, magnetic tape recording, and digital techniques is highly desirable.

Supervision: Shall be under the direct supervision of the Medical Instrumentation Engineer. In his absence shall report to the Assistant Chief Engineer.

Duties and Responsibilities: Install or assist with installation of new electronic equipment and systems in the Medical Center.

Perform repairs and modifications on electronic equipment and systems such as chart recorders, magnetic tape recorders, stimulators, defibrillators, temperature measuring units, and calibrate these units at specified intervals.

Construct, as directed, new electronic equipment for use in the Medical Center.

Assist the Medical Instrumentation Engineer in maintaining records of the age, location, status, and configuration of all electronic equipment in the Medical Center.

Shall assist doctors and nurses, when requested, in connecting and using patient monitoring equipment, and in overcoming problems related thereto.

Shall made pick-ups and deliveries of parts and equipment to and from local suppliers and repair facilities.

Shall assist the Medical Instrumentation Engineer in procuring and maintaining spare parts inventory necessary for continued functioning of the shop.

Shall be present for work at the assigned times attired in clean clothes, shoes, and shall practice personal hygiene in a manner consistent with the cleanliness required of

persons working in a hospital and coming in contact with pa· tients.

Shall read trade periodicals and participate in educational organizations and associations to further his knowledge of the trade.

Shall perform such additional duties as required and necessary.

APPENDIX K. SOME TRAINING PROGRAMS

APPENDIX K

SOME TRAINING PROGRAMS

As stated in the chapter on Training, we found several existing BMET training programs, as well as some fairly formal training programs in large medical instrument manufacturers. Following are descriptions of the programs that we found in colleges, technical institutes, and the military, as well as four representative manufacturers' training programs. These are examples; there may well be other formal training programs.

U.S. ARMY MEDICAL OPTICAL AND MAINTENANCE AGENCY (USAMOMA) MEDICAL EQUIPMENT MAINTENANCE TRAINING COURSE FITZSIMONS GENERAL HOSPITAL DENVER, COLORADO

The training program at USAMOMA, located at Fitzsimons General Hospital, was started by the Army in 1945 on the basis of need growing out of World War II. The Army felt the need to establish and then to expand and upgrade an internal medical equipment maintenance staff. The training program is autonomous - there is no formal collaboration with other schools, hospitals, or employers of BMET's. The Army,through special arrangements with manufacturers, has acquired complete sets of wiring diagrams, schematics and repair tools for a variety of different pieces of medical equipment; through adequate funding they have been able to acquire many of the kinds of medical equipment necessary for a comprehensive BMET training program. The Army training program can afford to remain autonomous.

The program has multiple entry points, as three levels of instruction are given.

(1) Basic electro-mechanical and electronics course, 13 weeks: The purpose of this course is to train men to install, inspect, maintain, repair, and calibrate mechanical and electro-mechanical medical equipment (with fewer electronic components). The prerequisite is high school level algebra or equivalency testing in

algebra, plus a certain amount of active duty service remaining after completion of the course. Seventy-two hours are spent on electricity, 347 hours on maintenance and repair of medical equipment, and 38 hours on maintenance management and special techniques.

(2) Advanced electronics and X-ray courses, 33 weeks: The purpose of this course is to train men to install, inspect, maintain, repair, calibrate, and adjust selected electrical and electronically controlled or operated medical equipment, including X-ray apparatus. The prerequisite for this course is completion of the basic course, with a number of months of active duty service remaining after completion of the course. The course consists of 310 hours of electricity and electronics, 730 hours of maintenance and repair of medical equipment, and 47 hours of maintenance management. More hours are spent on practical exercise than in lecture. No actual clinical or work experience is part of the program, but a great deal of time is spent in simulated work situations. The emphasis on physiology/anatomy is not as great as it may be in other BMET courses, as the graduate from this program will invariably be working side-by-side in the field with a medical technologist.

(3) Refresher courses which introduce new medical equipment that have come into the field, 6 weeks: Entry requirements are set by rank and previous training or acceleration testing, as determined by the U. S. Army.

The program is offered continuously, on a full-time basis. Normal class size is 15, with a student/instructor ratio of 8 to 1. There are presently 135 enrolled in the program - which should remain fairly constant. The majority of the trainees are high school graduates and, at least in the short course, men drafted into the Army. More than half of them have come straight from school into the Army; 30% have had some work experience as medical technicians. In the past year there were 181 graduates out of the 248 who enrolled. Since 1945 approximately 5,000 out of 7,000 men have completed the course. An estimated 30% of those are still in the Army, and an additional 20% are still working for the U. S. government in some biomedical equipment repair capacity. Small numbers are probably working in hospitals or for medical instrument manufacturers as BMET's. The only reason offered as to why as many as 40% may have left the field is that there is better pay in other fields. There are 38 full-time instructors (2 engineers, 36 U.S. Army Mos. 35G40H or 202A8 instructors), 6 part-time instructors, who also function as

administrators, and one test evaluator.

U. S. AIR FORCE MEDICAL EQUIPMENT REPAIR COURSE
SHEPPARD AIR FORCE BASE
WICHITA FALLS, TEXAS

The U.S.A.F. Medical Equipment Maintenance Program was started in 1958 as a 20-week course. Within the past six months the program has been revised, and is presently self-paced, and 45 weeks in length. The structure of the program is as follows:

15 weeks - basic electronics

3 weeks - troubleshooting techniques

3 weeks - management of maintenance

21 to 24 weeks - self-paced instruction, practical repair and calibration exercises on approximately 100 items of hospital equipment

Basic to the self-paced instruction are what are called Program Instruction Packages (PIPs) which are instructional modules. Each of the approximately 35 PIPs includes the following:

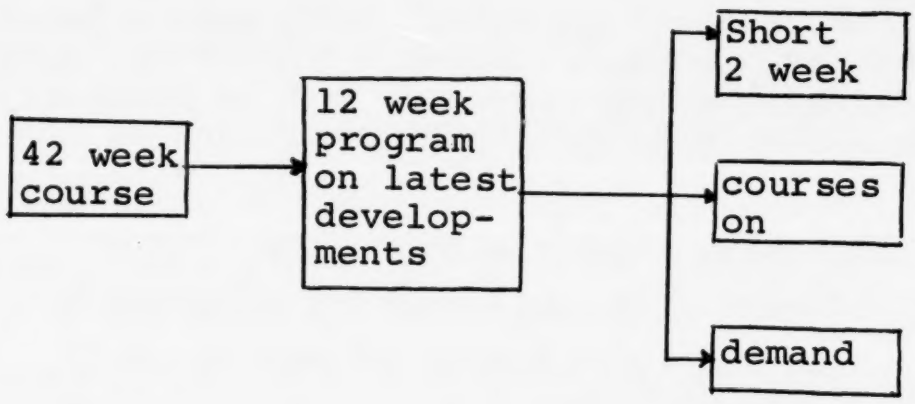
PIPs
- Tools
- Test Equipment
- Manufacturer's literature
- Item of equipment
- Study guides and procedures for the student
- Audio-visual aids
- Visual aids

The student can select any PIP available and is expected to work at his own rate under an instructor's supervision. Satisfactory completion of the PIP is demonstrated by 100% accuracy in (1) inspection, (2) operation and troubleshooting, (3) repair of diagnosed malfunctions, and (4) recording work report, maintenance record forms, etc. As soon as the student completes the PIPs he can graduate. The last 19 graduates have completed the program, on the average, in 39 weeks.

Approximately 10% of the student's time is spent in lectures; the remaining 90% is spent in lab and self-study. Standard textbooks account for 10% of the instructional materials used, materials developed by the Air Force account

for 40%, and literature from manufacturers account for the other 50%. The Air Force has 16 faculty staff members teaching biomedical courses.

More advanced programs are also being planned:



In terms of numbers, the Air Force program is much smaller than the Fitzsimons (Army) program. There are about 80 admissions per year; of those, approximately 72-75 graduate. The five to eight students who do not complete the program are attributed to "poor selection" and they transfer to another course.

BIOMEDICAL ELECTRONIC TECHNOLOGY PROGRAM
LINCOLN COLLEGE, NORTHEASTERN UNIVERSITY
360 HUNTINGTON AVENUE
BOSTON, MASSACHUSETTS

Lincoln College of Northeastern University initiated its program leading to an Associate in Engineering degree in Biomedical Electronic Technology in 1963. The program is a balance between traditional electronics, biological sciences, and specialized electronics.

Lincoln College regularly operates as a part-time technical institute for Northeastern University, with a total enrollment of over 11,000 students. It is difficult at any one time to determine exactly how many students are in a particular program. In the past two years, however, the program has graduated at least 12 BMET's.

The course of study is four years (evenings) in length. The majority of the students are employed full-time by medical instrument manufacturers who generally pay tuition to the program. The attrition rate is very high due to the difficulty of the course.

The program consists of the following:

Mathematics through Integral Calculus
Basic Electronics through Amplifiers
Physical Science through Solid State Physics
Biological Science through Physical Chemistry
Specialized Electronics through Medical Instruments and Systems

The student divides his time equally between lecture and lab. The materials used include standard textbooks, instructional modules, and instrument manufacturers' literature. The instructors in the program all teach part-time, since they are all employed full-time as professionals in industry.

The graduates of the program generally continue employment in the company that has sent them to school. However, they are eligible to apply for admission to the Bachelor of Science (Electronic Engineering) program at the School of Engineering, or to continue toward a Bachelor of Electronic Technology at Lincoln College.

BIOMEDICAL ENGINEERING PROGRAM
ALGONQUIN COLLEGE OF APPLIED ARTS AND TECHNOLOGY
1385 WOODROFFE AVENUE
OTTAWA, ONTARIO, CANADA

The BMET training program at Algonquin College was started in September 1967, and has graduated 22 technicians since then.

The program began in response to interest by the Ottawa Hospital Council for paramedical courses in November, 1966. A full-time instructor with experience working for Picker X-Ray and teaching at a local high school was hired. Five part-time instructors teach different aspects of the two-year technician course; four of them are from other departments in the college, and the fifth part-time instructor is a technologist in the Bio-Medical Engineering Department at the Ottawa Civic Hospital.

The Bio-Medical Engineering Department staff at the Ottawa Civic Hospital has been very cooperative in taking students for work experience, sitting on the Advisory Committee and providing lecturers.

The curriculum has changed somewhat since the course began. X-ray is now de-emphasized and electronics training has been increased, especially in regards to computers. The increased emphasis on electronics is due largely to the

difficulty the school has had in placing its graduates in hospitals. Most graduates go to work in medical equipment manufacturers as salesmen or servicemen, and the companies demand a thorough electronics background. The hospitals are not developing Bio-Medical Engineering Departments, despite the apparent success of the Civic Hospital system.

The BMET is expected to operate equipment, to do calibration and minor repairs, and to improvise equipment for special needs. The present course consists of approximately 55% theory and lab, and 45% "related work" including life sciences and courses such as Math and English.

The students are recruited through local high school guidance counsellors; the college also gives lectures outlining all of the technical programs which they offer. Approximately 6 to 10 students drop out of the BMET program yearly, most of whom transfer to the Electronics program. Algonquin College will be gathering data to determine where the graduates of all their different programs end up. This will be done with the aid of a placement officer.

BIOMEDICAL ELECTRONICS PROGRAM
BRITISH COLUMBIA INSTITUTE OF TECHNOLOGY
3700 WILLINGDON AVENUE
BURNABY 2, BRITISH COLUMBIA, CANADA

B.C.I.T. has a two-year Diploma of Technology Biomedical Electronics program that has been running since September, 1967. It was begun through the recommendation of the Advisory Committee, made up of local leaders in the field. The director, Mr. A. Ridgway, now has two full-time staff members who teach primarily equipment design and repair; staff from other affiliated departments teach electronics, mathematics, anatomy, and physiology, biophysics, and so on.

The first year of the program consists of 50% electronics and 50% basic courses (like English) and life sciences. The second year includes clinical field experience at St. Paul's Hospital, which has an energetic Biomedical Engineering Department -- in fact the only one of its kind in the city. The student also continues to study biomedical electronics and related subjects, such as digital techniques.

The school has a reputation of requiring hard work from its students. If a student fails any one of his courses he must automatically leave the school, but may repeat that course the next term it is offered. However, graduates of the B.C. Institute of Technology are highly regarded by

employers in the Province and the rest of Canada.

Thus far the Biomedical Electronics program has produced 8 graduates, 2 women and 6 men. These have been placed in local hospitals, universities, and medical instrumentation companies. The type of work for which these technologists have been employed includes physiological research in aquatic mammals, the study of the functions of the eye, pulmonary physiology in exercise, and the sale and repair of biomedical instrumentation. One-third of the present junior class of 15 are females.

SAN MATEO COMMUNITY COLLEGE
1700 WEST HILLDALE BOULEVARD
SAN MATEO, CALIFORNIA

San Mateo's BMET training program was started three years ago as a joint cooperative effort between Dr. Knowle Thompson and the heads of the electronic and biology departments. No one received funds to establish the pilot program and so they were, in effect, donating their time and equipment. The biology department head left the college for another position in the state system, and the electronics department head left teaching and returned to industry. The new department heads refused to donate their time and equipment to the pilot program without funding. An NIH grant application was made, but the project was not funded, resulting in the program's being discontinued.

A unique feature of this program was that it was aimed primarily at women, for two reasons. First, it was felt that female BMET's would be able to get along better with the nursing staff; therefore, the focus of the program was on the equipment that nurses were most likely to operate (EKG monitors). Second, women would not be as attractive to industry located in the vicinity. Most of the men enrolled in the electronics program are "scooped up" by industry before they can complete the two-year program. The initial enrollment in the pilot program was 30 students, but by the end of the first semester the class was reduced to 15. By the end of the first year, only one student remained. During its three years of operation, the program graduated two female BMET's, one of whom has since left the field and is now selling sweaters at Sak's Fifth Avenue.

The program was designed to produce an operator/technician. The students seemed to have most of their difficulty with electronics. If Dr. Thompson were to start the program over again, he said he would introduce electronics more

gradually and over a much longer time span, but he would still recruit girls.

BIOMEDICAL EQUIPMENT TECHNOLOGY PROGRAM
SPRINGFIELD TECHNICAL COMMUNITY COLLEGE
ARMORY SQUARE
SPRINGFIELD, MASSACHUSETTS

STCC's interest in a BMET program was stimulated by a city health official's concern for maintenance of local hospital equipment. A grant was obtained from the United States Office of Education by TERC to support development of a pilot curriculum at STCC. Despite a number of problems resulting largely from delays in receipt of Federal funds, the program was introduced on an experimental basis in September 1967 and has been developed steadily since then.

Twenty students enrolled in the first class, and 14 graduated in June 1969. Like so many of the schools whose programs are summarized here, STCC has found a number of hospitals unprepared to make effective use of BMET's. Nevertheless, of the first 14 graduates, four found BMET jobs immediately, and one or two since then have found positions in local hospitals; another is pursuing higher education. Four graduates accepted employment as an electronics teacher, a laser technician, a mechanical technician, and a chemical technician, respectively. Three BMET's entered military service, and one or two obtained non-technical jobs. The second STCC class, due to graduate in June 1970, started with 19 students, and between 14 and 16 are expected to complete the course. Several of these students have been accepted for full-time studies in engineering programs, and one has been given full transfer credits from STCC to enroll in the pre-med program at a local college.

The BMET student at STCC spends approximately 50% of his time in lectures and 50% in lab work. Courses are heavily oriented toward electronics and biomedical equipment, with some English (report writing) and life sciences. Some self-written instructional materials are used, but emphasis has been on existing texts and lab exercises, with about 20% manufacturers' literature.

Through a program of weekly Biomedical Seminars, STCC brings physicians, hospital technicians, and industry representatives into the lab to demonstrate specialized equipment. Interdisciplinary integration and application of student skills and knowledge to real job situations is developed at these discussions, and students get a feeling for the

variety of people and apparatus they are likely to encounter in the BMET field.

BIOMEDICAL EQUIPMENT TECHNOLOGY PROGRAM
TEXAS STATE TECHNICAL INSTITUTE
WACO, TEXAS

TSTI was selected as the second pilot school in which TERC could utilize and evaluate BMET curriculum and training methods. Its BMET programs were not begun until January 1969, the delays being due to (1) the need to revise the Springfield BMET curriculum to suit TSTI's six - trimester program; and (2) the fact that many of the students who applied for admission to the BMET program at Waco needed pre-technology courses.

Originally, there were 8 students in the two-year program at TSTI, including several students from the one-year medical repairman course who moved into the two-year program. The other students in the one-year program dropped out, or transferred to other programs. Consequently, the one-year program was discontinued. The two-year program is expected to graduate approximately 6 to 8 students in their first class.

The student's time is about equally divided between lectures and labs. During the first two trimesters, the student focuses on the "background" to medical equipment, including physiology and anatomy and introduction to the operation and use of equipment. He also begins studying circuits, and so on. The third and fourth trimesters, the students focuses on the electronics of the instruments, starting with simple medical equipment and moving into more sophisticated medical instrumentation by the second year. TSTI develops about 30% of its own instructional materials, uses standard textbooks for about 60% of the instruction, and uses manufacturers' manuals for the remaining 10% of the instruction.

BIOMEDICAL ENGINEERING TECHNOLOGY
MONROE COMMUNITY COLLEGE
1000 E. HENRIETTA ROAD
ROCHESTER, NEW YORK

Monroe's two-year BMET program in Rochester, New York has been in existence since September 1967. They began with five students and graduated four, with one student dropping out because he was not suited to the program. The September 1968 class had four students, all of whom are expected to graduate in June 1970. Eight students entered the college in the September 1969 class, and thus far, four have transferred out.

The last four drop-outs are attributed to poor screening by the admissions department. In order to alleviate this screening problem, the program coordinator now personally interviews each program applicant herself, and actively recruits students by talking in high schools with both guidance counselors and students.

The first four graduates of the BMET program had little difficulty getting good jobs. All are making salaries between $8,000 and $9,000 a year. One set up his own BME department at a local hospital, two are employed in research labs, and the fourth works for a medical contract maintenance company.

There is presently one full-time instructor in the department - the coordinator herself. The electronics component is, taught by the Electronic Technology Department, with the result that "the students learn about 25% more electronics than they need to know." The program coordinator acknowledges the difficulties in using other departments for teaching sections of the course, but because the program is so small she has no alternative.

The technicians from the Monroe program are trained primarily to do preventive maintenance and minor repairs, and to be able to make decisions about how to handle major repairs, whether to lease equipment, and so on.

The student spends approximately 45% of his time in lectures, 45% in labs, and 10% of his time in clinical experience (last semester). Standard textbooks account for approximately 50% of the instructional materials, the other 50% being self-developed materials.

BIOMEDICAL TECHNOLOGY
GROSSMONT COLLEGE
8800 GROSSMONT COLLEGE DRIVE
EL CAJON, CALIFORNIA

Grossmont College's Biomedical Electronic program began in September 1968 as a specialty area of the Engineering Technology program. Courses in the Electronic Instrumentation program were modified to include biomedical equipment and applications, and students were integrated into other health science programs for instruction in anatomy, physiology, and chemistry. To graduate the student must have completed the Engineering Technology program in mathematics, physics, engineering drawing, and manufacturing processes, the general education requirement, and the major course requirements in the field of Biomedical Electronics (20 or more units). The

student also serves an internship at a local medical center, working with their technicians, for 8 months, and similar arrangements are being made with other local hospitals and research institutes.

The program seems to be shifting its focus from general repair technicians to specialized operator/repair technicians. In a presentation at the Biomedical Technology and Manpower Conference at Grossmont College in March 1970, the head of the program stated:

> "Along the way in developing this program, we have discovered that we have reached the area of specialization in some Biomedical Technology fields. Rather than developing a general biomedical technician with a broad background in medicine and medical equipment, we discovered that we are going to need a technician in other areas who will be specialists. Some of these will work as the Biomedical Electronics Technician in body monitoring, in the EKG, EMG, and EGG signal recording; others may be utilized in the cardiopulmonary and/or cardiac catheterization laboratories. Still other technicians will be working in the clinical research areas which will include the use of computers, and a fourth area is that of the calibration, standards, and repair-type technician."

Grossmont College is also working on an arrangement with the United States Navy Hospital Corps School at Balboa Naval Hospital in nearby San Diego, California, whereby Grossmont will give Navy corpsmen general background and some theory and education courses, and the Navy Hospital Corps School will give Grossmont's students specialty training and some of their clinical experience. Presumably, this cooperative venture will help corpsmen obtain Associate degrees and allow Grossmont College to expand into specialty areas without having to invest in additional equipment and teaching staff.

GENERAL ELECTRIC MEDICAL SYSTEMS DEPARTMENT
4855 ELECTRIC AVENUE
MILWAUKEE, WISCONSIN

General Electric recruits X-ray and biomedical service technicians through a number of district and local offices as well as through its headquarters personnel group. Recruiting is directed toward men having at least a two-year Associate degree in mechanical and/or electronic technology.

Candidates having equivalent training (comprehensive electronic training during military service) or work experience are also considered.

Applicants are tested for mechanical, electrical, and electronic aptitude as well as for problem-solving ability in order to plan an appropriate training and work-experience program for the development of the individual.

The actual training program for each new service technician may be varied somewhat as indicated by his formal training and work experience. Generally he is started immediately on a course of indoctrination in the work routines and procedures of a district or local office. Study materials, appropriate for his background and experience, are selected and furnished to him. He is introduced to the hospital environment and medical field by taking part in actual equipment installation under the direct supervision of an installation supervisor. This also gives the new man an opportunity to become familiar with the various pieces of equipment, their function and application while he is absorbing the written study materials.

After the new man has gained experience through study and installation work, he is introduced to the procedures for responding to routine and emergency service calls under the guidance of a supervisor or experienced service technician.

The training, outlined above, at the district or local office is supplemented by training courses offered at the headquarters of General Electric Medical Systems Department in Milwaukee. To meet the increasing demand for more training for more people, General Electric established the Medical Systems Institute; a $500,000 facility with over 12,000 square feet of floor space.

The Institute offers courses of several weeks duration in basic fundamentals of X-ray and biomedical equipment, as well as shorter courses directed toward specific equipment. Candidates for courses at the Institute are selected for similar background and work experience so that the couse has maximum effectiveness for a given group. The Institute prepares packaged courses and study materials for use by the district and local offices to train new men in basic fundamentals or to introduce experienced men to new products. The Institute maintains a record of each student and his progress as a guide to him and his manager in determining the results of training and future training needs.

Experienced technicians may return to the Institute periodically for refresher courses on new products. Seminars

are held to assist technicians in developing leadership and supervisory skills as well as in keeping up with new technology.

HEWLETT-PACKARD
MEDICAL ELECTRONICS DIVISION
175 WYMAN
WALTHAM, MASSACHUSETTS

Hewlett-Packard Service Technicians are hired by regional offices which hire only men with a good background in electronics, either through schooling or job experience. A written test is given to all applicants to determine their knowledge of electronics.

Although the factory office in Waltham, Massachusetts, provides training opportunities and personnel for all regions, each regional office is fairly autonomous in its training procedures, and the company's emphasis is going more and more toward regional training. The trainers are generally service managers who train on-the-job using Hewlett-Packard manuals, video tapes on service, products and applications, and any other materials they consider important. Company standards are kept up by performance appraisal in each office. Two seminars a year are held at Waltham, generally for more experienced technicians, with an emphasis on new products and service techniques. Also, Service Engineers make several field visits a year explaining new products to regional gatherings.

Some initial training does take place at the Waltham office. As defined by the Customer Service Manager there, this training program consists of 25% physiology and its applications to the instruments, 50% learning the instruments, and 25% lab. Two programmed texts are used: Medical Terminology by Smith and Davis (Wiley) and Anatomy and Physiology by Dean, Farrar, and Zolds (Lippincott).

BECKMAN INSTRUMENTS
SCIENTIFIC PRODUCTS INDUSTRIAL DIVISION
1117 CALIFORNIA AVENUE
PALO ALTO, CALIFORNIA

Beckman's training center in Palo Alto, California was started about seven years ago; prior to this, Beckman relied on BMET's from their suppliers for repair of their equipment. This proved to be unsatisfactory in terms of quality of repairs (and customer relations), so Beckman hired a training

staff and began to train their own technicians.

The job applicant is first given an electronics examination, which he must pass before he can be considered. Once hired, the trainee first studies pH meters via correspondence courses and simultaneously receives on-the-job training from one of the experienced technicians at the local division. Once he has completed the pH meter course, he takes an examination, and if he passes it, he then goes to California for the one-month U.V. course (spectrophotometers). How soon he completes the correspondence course and goes to California depends partially on the man's skills and aptitudes, and partially on when the next U.V. course is given. Until recently, the trainee went immediately to California for a six-week course that included both pH meters and U.V.; now California training is only on U.V. The California training is a combination of lecture and lab, and teaches the trainee everything he needs to know about operation, use, installation, troubleshooting, and repairing the U.V. equipment. The instructional manuals are developed by Beckman; no standard textbooks or video-tapes are used.

Upon completion of these basic courses, the trainee returns to the local division and works in the field with an experienced service technician. At some point, depending on the needs of the local division, the progress and skills of the new technician, and the scheduling of the courses in California, the technician returns to California for intensive training in one of three major areas: gas chromatography, liquid scintillation, or I.R. equipment. If the BMET stays with Beckman long enough he will probably receive additional training in at least one of the other areas, and maybe both. Experienced technicians occasionally return to California for advanced training in regards to major modifications or new equipment, but usually the California office sends some of its training staff to New Jersey to conduct the necessary sessions for east coast technicians. It is estimated that it takes approximately one year for a trainee with no previous experience in medical equipment to function competently and independently (reasonably) on pH meters, spectrophotometers, and one of the advanced areas (gas chromatography, liquid scintillation, or I.R.).

ELECTRODYNE
PROVIDENCE HIGHWAY
SHARON, MASSACHUSETTS

Electrodyne training has changed greatly over the past several years to become a very brief and informal "indoc-

trination" in Electrodyne equipment. This is possible because they are hiring more experienced men into the service section of the company.

Currently, a man must have an extensive electronic background before being hired. Most of the "trainees" have experience in radio and TV and/or are graduates of a post-high school electronics school. These men are recruited by region, usually through newspaper advertising and sometimes through personnel agencies. Then, all men[1] are sent to the head office in Sharon, Massachusetts for two weeks of training in the plant. There is no electronic theory given during the two weeks -- it is assumed that all men are thoroughly grounded in electronics and need only specific introductions to Electrodyne equipment.

Training consists of the introduction to troubleshooting specific instruments using manuals containing schematic diagrams. Each serviceman keeps a set of these manuals (five volumes). Training also includes a study of heart physiology (as their equipment is primarily cardiovascular) and hospital protocol: how to act in the hospital, hospital environment, etc.

Training after the two week orientation is on-going in the field. A man reports to a regional manager or supervisor. He is allowed to handle simpler calls alone from the beginning, going along with his supervisor on more complex problems. Within four to six months, a serviceman can handle 90% of all calls alone; after six months to a year, 95% of calls. One percent of all calls require engineering assistance from the factory.

During the two week training session the men are evaluated by the instructor. However, no one has yet has been dropped during training -- the course can be slowed down or accelerated according to the ability of the trainee. This flexibility is possible because of the informal nature of the training. The two week periods are on-going, held whenever needed.

Electrodyne used to hold seminars in minor repair and troubleshooting for hospital personnel. The field servicemen recommend electricians or electronics technicians from hospitals across the country to attend (all but transportation paid by Electrodyne) three day sessions. These were held

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1. Including men servicing equipment overseas through international dealers. These international men are all engineers because of the complete range of services they must perform.

monthly, with only 12 people per course. They offered a choice between tub circuit (old equipment) and solid state (newer equipment) courses, depending on the equipment the hospital had. Many people attending these seminars were from the military. The seminars have been temporarily suspended pending development of a more comprehensive (and longer) hospital technician training course which is expected to be held on a fee-paid basis.

APPENDIX L. SAMPLE PROGRAM CURRICULA

APPENDIX L

SAMPLE TRAINING PROGRAM CURRICULA

Following are sample curriculum outlines from three community college two-year training programs for biomedical equipment technicians.

Curriculum I: Texas State Technical Institute

Curriculum II: Grossmont College

Curriculum III: William G. Welch, Western Wisconsin Technical Institute

These are included to give the reader an idea of how these colleges have organized the content of their programs.

CURRICULUM I

BIOMEDICAL EQUIPMENT TECHNOLOGY
Texas State Technical Institute
James Connolly Campus
Waco, Texas 76705

First Trimester	Hours per Week Class	Lab.	Cr.
BET 100 Occupational Guidance	0	3	1
BET 150 Physiology	3	0	3
ELT 150 D.C. Circuits	3	3	4
IDT 123 Electronic Drafting	2	4	3
MTH 101 Slide Rule	1	0	1
MTH 124 Technical Mathematics I	3	0	3
TWG 101 Technical Communications	3	0	3
	15	10	18

Second Trimester			
BET 160 Biomedical Equipment	0	3	1
ELT 160 A.C. Circuits	3	3	4
ELT 165 Semiconductors	3	3	4
MTH 102 Slide Rule	1	0	1
MTH 134 Technical Mathematics II	3	0	3
PHY 120 Applied Physics I	3	3	4
	13	12	17

Third Trimester			
CHT 102 Applied Chemistry I	3	3	4
ELT 180 Instruments & Measurements	3	3	4
ELT 185 Electronic Devices	3	3	4
MTH 141 Technical Mathematics III	3	0	3
PHY 121 Applied Physics II	2	3	3
	14	12	18

Forth Trimester			
BET 250 Biophysics	2	0	2
CHT 220 Organic Analysis	3	3	4
ELT 250 Communication Circuits	3	6	5
ELT 255 Pulse Circuits	3	3	4
TWG 103 Technical Communications II	3	0	3
	14	12	18

Fifth Trimester		Hours per Week Class	Lab.	Cr.
BET 260	Biomedical Instrumentation I	3	3	4
ELT 155	Shop Processes I	2	3	3
ELT 260	Computer Circuits	3	3	4
INT 281	Automatic Control Principles	3	3	4
TWG 106	Oral Communications*	3	0	3
		14	12	18

*May substitute with departmental approval.

Sixth Trimester				
BET 261	Biomedical Instrumentation II	5	6	7
BET 270	Medical Backgrounds	1	0	1
BET 280	Personal Development	3	0	3
CHT 230	Physiological Chemistry	3	3	4
	Elective	—	—	3
				18

MAJOR COURSES

BET 100 Occupational Guidance 0 3 1

An introductory course designed to acquaint the student with the biomedical equipment and the industry.

BET 150 Physiology 3 0 3

A course in basic human physiology. Emphasis is placed on those aspects which will enhance the student's comprehension of the needs and applications of biomedical equipment.

BET 160 Biomedical Equipment 0 3 1

An introduction to the major types of biomedical equipment. The student is familiarized with the basic principles incorporated in the design of the equipment and is acquainted with its use and operation. Prerequisite: BET 100.

BET 250 Biophysics 2 0 2

A study of biological systems from the physics standpoint. The generation of biopotentials, effect of ultra-sonic and radioactive irradiation on living

		Hours per Week Class	Lab.	Cr.

tissue, circulatory dynamics, etc. are typical topics study. Prerequisites: BET 150, BET 160, ELT 185, and PHY 121.

BET 260 Biomedical Instrumentation I 3 3 4

A study in depth of the operation and maintenance of biomedical apparatus. Emphasis is placed on therapeutic and clinical equipment. Prerequisite: BET 250.

BET 261 Biomedical Instrumentation II 5 6 7

A comprehensive course in the operation and maintenance of a variety of biomedical instruments. Primarily, intensive care, monitoring, and research apparatus, including transducers. Prerequisite: BET 260.

BET 270 Medical Backgrounds 1 0 1

A course designed to acquaint the student with terminology of medical profession, ethics, protocol, and hospital practices and procedures.

BET 280 Personal Development 3 0 3

A course designed to make the student aware of personal qualities which will enhance his possibility of future success in a paramedical field. Appropriate outside speakers are invited to lecture. Employment alternatives are discussed.

ELECTRONICS

ELT 150 Direct Current Circuits 3 3 4

This course presents an introduction to electrical theory on the basis of direct current with an emphasis on contemporary techniques as a supplement to basic concepts. Covers the principles of electron physics, unidirectional currents and factors affecting its magnitude, series circuit analysis, parallel-circuit analysis, analysis, series parallel-circuit analysis, complex unidirectional-current circuits, and the phenomena of magnetism. Prerequisite: MTH 124 or registration therein.

		Hours per Week Class	Lab.	Cr.
ELT 160	Alternating Current Circuits	3	3	4

A continuation of electrical theory on the basis of alternating currents with an emphasis on contemporary techniques as a supplement to basic concepts. Covers the analysis of the sine wave, series circuit with sine wave input, series resonance, parallel circuits with sine wave inputs, parallel resonance, the non-resonant circuits and transformers. Prerequisite: ELT 150 and MTH 131 or registration therein.

ELT 165	Semi-Conductors and Vacuum Tubes	3	3	4

A course designed to familiarize the student with semi-conductors and vacuum tube fundamentals, construction and characteristics. Multisection and special purpose semi-conductors and vacuum tubes will be studied. Prerequisite: ELT 160 or registration therein.

ELT 180	Instruments and Measurements	3	3	4

A course concerned with the theory of electronic test instruments, proper use of instruments, accuracy and limitation of measurements, and calibration techniques. Prerequisite: ELT 165 or registration therein.

ELT 185	Electronic Devices	3	3	4

A course concerned with electronic devices and their characteristics (solid state and vacuum tube device characteristics are covered). This course utilized mathematics as a tool in analyzing basic electronics circuits. Prerequisites: ELT 165 or registration therein.

ELT 250	Communication Circuits	3	6	5

A continuation of the Electronic Devices course concerning class "A", class "B", and class "C" amplifiers, oscillators, modulation, small signal tuned amplifiers, and detector circuits. Prerequisite: ELT 185.

ELT 255	Pulse Circuits	3	3	4

Begins with an introduction to pulses. Includes the theory and operation of limiter and clipper circuits, differentiating and integrating circuits, and D-C

		Hours per Week Class	Lab.	Cr.

restoration. Prerequisite: ELT 185.

ELT 155 Shop Processes I 2 3 3

This course is designed to introduce the student to the use of common hand tools, test equipment and other general instruments used in the installation and construction of electronics equipment. Emphasis will be placed on reliable electrical connection techniques, wiring, lacing and chassis lay-out and construction.

ELT 260 Computer Circuit Analysis 3 3 4

This course introduces information pertaining to both analog and digital computers. Emphasis is placed on the principles of operation and on circuitry used in these computers. The binary number system and Boolean algebra are covered. Prerequisite: ELT 185.

MATHEMATICS

MTH 101 Slide Rule 1 0 1

Slide rule manipulations used in the solution of problems of the type found in Technical Mathematics.

MTH 124 Technical Mathematics I 3 0 3

A comprehensive study of algebra, including equations, inequalities, determinants, progressions, partial fractions and graphical representation.

MTH 102 Slide Rule 1 0 1

A continuation of MTH 101. Prerequisite: MTH 101.

MTH 134 Technical Mathematics II 3 0 3

Definitions of functions, evaluation of functions of special angles, solutions of triangles, logarithms, inverse functions, trigonometric equations. Prerequisite: MTH 124.

		Hours per Week Class	Lab.	Cr.
ELT 160	Alternating Current Circuits	3	3	4

A continuation of electrical theory on the basis of alternating currents with an emphasis on contemporary techniques as a supplement to basic concepts. Covers the analysis of the sine wave, series circuit with sine wave input, series resonance, parallel circuits with sine wave inputs, parallel resonance, the non-resonant circuits and transformers. Prerequisite: ELT 150 and MTH 131 or registration therein.

ELT 165	Semi-Conductors and Vacuum Tubes	3	3	4

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A course concerned with the theory of electronic test instruments, proper use of instruments, accuracy and limitation of measurements, and calibration techniques. Prerequisite: ELT 165 or registration therein.

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A continuation of MTH 101. Prerequisite: MTH 101.

MTH 134 Technical Mathematics II 3 0 3

Definitions of functions, evaluation of functions of special angles, solutions of triangles, logarithms, inverse functions, trigonometric equations. Prerequisite: MTH 124.

		Hours per Week Class	Lab.	Cr.
MTH 141	Technical Mathematics III	3	0	3

Concepts of analytical geometry. Some differential and integral calculus will be introduced with applications in electronic analysis stressed. Prerequisite: MTH 134.

PHYSICS

PHY 120	Applied Physics I	3	3	4

Units of measurement, principles and applications of mechanics, heat and sound with emphasis on fundamental concepts, applications, and solutions of practical problems. Prerequisite: MTH 134 or registration therein.

PHY 121	Applied Physics II	2	3	3

Concepts of wave motion; generation, transmission and detection of sound, light, illumination and the principles involved in optical instruments. Prerequisite: PHY 120.

CHEMISTRY

CHT 102	Applied Chemistry I	3	3	4

Fundamental laws and theories of chemical activity. Practical applications of chemical processes. Laboratory experiments deal with non-metals and tests of technical importance. Prerequisite: MTH 124.

CHT 220	Organic Analysis	3	3	4

Identification of organic substances by spectrophotometric analysis. Instrumental analysis will include infrared, ultraviolet and visible spectroscopy.

CHT 230	Physiological Chemistry	3	3	4

A course designed to familiarize the student with the bio-chemistry of human systems. Emphasis will be placed on chemistry of blood and anzymes.

CURRICULUM II

BIOMEDICAL TECHNOLOGY PROGRAM
Grossmont College
El Cajon, California

First Semester	1st Semester Units
Electronics Core 1	12
Medical Terminology 1 (ELEC 199)	1
General Education	3
*Physical Education	1/2
	16 1/2

Second Semester	
Electronics Core 2	12
Medical Terminology 2 (ELEC 199)	1
Anatomy-Physiology 124	4
Physical Education	1/2
	17 1/2

Summer Session	
General Education	6

Third Semester		
Electronic Instrumentation,	ELEC 205	4
Electronic Instrumentation,	ELEC 235	4
Chemistry	CHEM 115	4
Computer Programming	ENGR 230	1
Physical Education		1/2
General Education		5
		17 1/2

Fourth Semester	
Biomedical Instrumentation 1, ELEC 233	4
Biomedical Instrumentation 2, ELEC 237	4
Electives in Major	4
General Education	6
Physical Education	1/2
	18 1/2

*Students 21 years of age or older will have the physical education requirements waived.

MAJOR COURSES

ANATOMY

ANATOMY-PHYSIOLOGY 124

4 units
2 hours lecture
6 hours laboratory
Prerequisite: High School chemistry or equivalent.

ANATOMY-PHYSIOLOGY

Structural systems of the human body, their functions, and interrelationships are studied. Emphasis is placed upon circulatory, digestive, muscular, and nervous systems. In the laboratory, experimental techniques are utilized.

ANATOMY 140

4 units
2 hours lecture
6 hours laboratory
Prerequisite: Introductory course in high school or college biology.

HUMAN ANATOMY

Structural systems of the human body with emphasis evenly divided between gross anatomy and the cellular detail of tissue. The cat is used as a dissection specimen in the laboratory along with supplementary human organs and tissue slides. The course meets the anatomy requirement for B.A. nursing majors and a variety of paramedical fields.

CHEMISTRY

CHEMISTRY 115

3 units
2 hours lecture
3 hours laboratory
Prerequisite: Mathematics 105 or equivalent.

FUNDAMENTALS OF CHEMISTRY

Elementary principles of inorganic and general chemistry. Previous chemistry background is not required. Recommended for students who wish to pursue courses in nursing, home economics, etc.

ELECTRONICS

ELECTRONICS 110

3 units
2 hours lecture
3 hours laboratory
Prerequisite: None

INTRODUCTION TO BASIC ELECTRONICS

A basic general course for the beginning student without any previous experience in electronics. Covers the necessary

ELECTRONICS 110 - Con'd

information for introductory education in the principles of electronics starting with the atom, and progressing to the simple DC and AC circuits and the everyday use of electronics in today's technical world. The applications and future implications of the role of electronics in architecture, communications, aerospace, oceanography, medicine, and industry, for the student and society in general will be studied.

ELECTRONICS 122

DC CIRCUIT ANALYSIS

4 units
3 hours lecture
3 hours laboratory
Prerequisite: Mathematics 115 or equivalent; Physics 120 or equivalent; or concurrent enrollment.

Electronics, charges, fields, electric sources and units; series, parallel and compound DC circuits analysis; DC measurements; inductors, capacitors and RC timing circuits.

ELECTRONICS 124

AC CIRCUIT ANALYSIS

4 units
3 hours lecture
3 hours laboratory
Prerequisite: Electronics 122 or equivalent; Mathematics 116 or equivalent; Physics 121; or concurrent enrollment.

Alternating current waveform analysis; AC measurements; admittance and impedance; phase angle measurements; series and parallel resonance; frequency response measurements.

ELECTRONICS 126

TRANSITOR FUNDAMENTALS

4 units
3 hours lecture
3 hours laboratory
Prerequisite: Electronics 122 or consent of instructor; Mathematics 116 or equivalent; Physics 121; or concurrent enrollment.

Semiconductor physics; junction phenomena; fundamentals of transistor action, biasing techniques. Properties of low frequency amplifiers; use of precision electronic laboratory equipment during investigation of the above.

ELECTRONICS 199

1-3 units
1-9 hours laboratory
Prerequisite: Consent of instructor.

SELECTED PROJECTS IN ELECTRONICS

Course content, semester offered, and unit credit to be determined by the Engineering and Technology Department in relation to community and student interest and/or available staff. Course may be repeated for a maximum of 12 units.

ELECTRONICS 205

4 units
3 hours lecture
3 hours laboratory
Prerequisite: Credit or concurrent enrollment in Electronics 124; experience or consent of instructor.

ELECTRONIC INSTRUMENTATION COMPONENTS

Introduction to electronic instrumentation used in oceanography, aerospace, and biomedical electronic engineering. Measuring, recording and displaying physical, physiological, chemical and electrical parameters. Includes the laboratory use of electronic counters, digital devices, amplifiers, oscilloscopes, cameras, X-Y plotters, signal generators, recorders, etc.

ELECTRONICS 237

4 units
2 hours lecture
8 hours field experience
Prerequisites: Credit in Electronics 235 or equivalent or consent of instructor.

ELECTRONICS, BIOMEDICAL INSTRUMENTATION III

Individuals from medical electronics industry and from hospitals and research facilities in the area will participate in lecturing and demonstrating specialized equipment used in diagnosis and therapy. Students will be required to take field trips to outstanding local institutions featuring medical electronics. The students will also spend a minimum of 8 hours in an assigned institution working for clinical experience. Students will also become familiar with reading and reporting on assigned topics in current medical and electronics literature.

MATHEMATICS

MATHEMATICS 105 — **FUNDAMENTALS OF ALGEBRA***

3 units
3 hours
Prerequisite: Mathematics 101 or equivalent.

An introduction to the basic properties of the integers, rational numbers, and real numbers; polynominal arithmetic, simple functions and relations, graphing, solving linear equations and inequalities, linear systems and second degree equations. Recommended for students with little or no recent knowledge of algebra.

MATHEMATICS 115 — **TECHNICAL MATHEMATICS**

4 units
4 hours
Prerequisite: Mathematics 105 or by examination.

An integrated course including algebraic operations, graphical analysis, an introduction to analytic geometry, right triangle trigonometry and vectors, exponents and radicals, slide rule operation. Problem solving is stressed.

MATHEMATICS 116 — **TECHNICAL MATHEMATICS**

4 units
4 hours
Prerequisite: Mathematics 115.

A continuation of Mathematics 115 including exponential, logarithmic and quadratic functions, trigonometric function analysis, operation with logarithms, variation, oblique triangles, and elementary statistics. Problem solving is stressed.

COMPUTER PROGRAMMING

ENGINEERING 230 — **ENGINEERING PROBLEM ANALYSIS**

1 unit
3 hours laboratory
Prerequisite: Mathematics 160.

Analysis of engineering problems and solutions using the digital computer. Fundamentals of programming and programming language commands.

* Student Development only--not required for major.

PHYSICS

PHYSICS 120

4 units
3 hours lecture
3 hours laboratory
Prerequisite: Concurrent enrollment in Mathematics 112 or Mathematics 115

GENERAL PHYSICS

A study of force and motion with emphasis on vectors; gravitation; work, energy, and power; structure and properties of matter; heat and temperature; wave motion and sound, electricity and magnetism.

PHYSICS 121

4 units
3 hours lecture
3 hours laboratory
Prerequisite: Physics 120

GENERAL PHYSICS

A study of electromagnetic phenomena, light and optical instruments; special relativity, quantum effects; nuclear and atomic physics including radioactivity.

CURRICULUM III

BIOMEDICAL ELECTRONICS
Proposed by William G. Welch, Sr.
Western Wisconsin Technical Institute
La Crosse, Wisconsin

First Quarter	Credit	Class	Lab
Communications Skills 1	3	3	0
Technical Mathematics 1	5	5	0
Electronic Methods 1	3	1	4
DC Circuits	4	2	1
*Introduction to Biomedical Electronics	3	2	2
	18	13	10
Second Quarter			
Communications Skills 2	3	3	0
Technical Mathematics 2	5	5	0
Technical Physics 1	3	2	2
AC Circuits	4	2	4
*Physiological Processes 1	3	2	2
	18	14	8
Third Quarter			
Social Science	3	3	0
Technical Mathematics 3	4	4	0
Technical Physics 2	3	2	2
Active Devices	4	2	4
*Physiological Processes 2	3	2	3
	17	13	9
Fourth Quarter			
Social Science	3	3	0
Technical Physics 3	3	2	2
Linear Electronic Circuits	5	3	4
Pulse Circuits	3	2	2
*Biomedical Techniques 1	3	2	2
	17	12	10

*Technical Core courses specifically developed for this technology.

Fifth Quarter	Credit	Class	Lab
Social Science	3	3	0
Social Science	2	2	0
Non-linear Electronic Circuits	4	2	4
Introduction to Computer Science	3	2	2
*Biomedical Techniques 2	3	2	2
*Medical Instrumentation 1	3	2	2
	18	13	10

Sixth Quarter			
Communication Skills 3	3	3	0
Social Science	3	3	0
*Biomedical Techniques 3	3	2	2
*Medical Instrumentation 2	3	1	4
*Medical Instrument Construction and Application	3	1	4
*Elective any area	3	2-3	0
	18	12-13	10

*Technical Core courses specifically developed for this technology.

BIOMEDICAL ELECTRONICS TECHNICAL CORE SUBJECTS

First Quarter

Introduction to Biomedical Electronics

3 Cr. 2 Class 2 Lab

General Introduction
- Hospital and Clinic Operation and Organization
- Regulations, Procedures
- Terminology
- Instrument Safety

Possible Lab Instruments
- Oscilloscopes
- Amplifiers
- Transducers
- Tape Recorders
- Power Supplies

Second Quarter

Physiological Processes 2

3 Cr. 2 Class 2 Lab

Physiological Processes
- Physiology and Anatomy of the Human Body
- Familiarization with Physiological Mesurements and Tests
- Gross Electrical Activity Monitroing Devices
- Introduction to Instrument Calibration

Possible Lab Instruments
- EKG
- EEG
- EMG
- Electrodes
- Autio Monitors

Third Quarter

Physiological Processes 2

3 Cr. 2 Class 2 Lab

Physiological and Chemical Processes
- Response Stimulus
- Fine Electrical Activity
- Basic Chemical Concepts
- Redox
- Chemical Equilibrium
- Human Related Chemistry
- pH Measurement
- Fluid Dynamics

Possible Lab Instruments
- pH Meters
- Blood Analyzers
- Automatic Balance
- Basic Chemical Analysic
- Additional Physiological Measurements

Fourth Quarter

Biomedical Techniques 1

3 Cr. 2 Class 2 Lab

Biological Processes
- Cell Structure
- Biological Measurements and Tests
- Terminology
- Relations to Electronic Lab Equipment

Possible Lab Instruments
- pH Meters
- Spectrophotometer
- Colorimeter
- Oscillographs

Fifth Quarter

Biomedical Techniques 2

3 Cr. 2 Class 2 Lab

Special Techniques
- Electrophoresis
- Ultra Violet Processes
- Spectrophotmetry
- Chromotography
- Flourescence
- Gamma Counting
- Closed Circuit TV

Possible Instruments
- Electrophoretic Apparatus
- Flame Photometer
- Chromatographs
- Isotope Equipment
- Closed Circuit TV

Medical Instrumentation 1

3 Cr 2 Class 2 Lab

Theory and Operation of Basic Measuring Instruments
Calibration and routine Maintenance Procedures

Possible Instruments
- Blood Analyzers
- Carrier Amplifiers
- Differential Amplifiers

Sixth Quarter

Biomedical Techniques 3

3 Cr. 2 Class 2 Lab

Research Techniques and Requirements
New Concepts
Things Predicted for the Near Future
X-ray
Ultra-Sonics
Lasers

Possible Instruments
- Recording Devices
- Observation Devices
- Medical Computers

Medical Instrumentation 2

3 Cr. 1 Class 4 Lad

Theory and operation of Biomedical Measuring Instruments
Calibration, Servicing, and Troubleshooting Techniques
Design of Electrodes
Thermography
Servo Mechanisms

Possible Instruments
- Automatic analyzers
- Micro-electronic Transmitters and Receivers
- Troubleshooting Problems

Sixth Quarter continued

Medical Instrument Construction
and Application

3 Cr. 1 Class 4 Lab

Problems in construction,
modification and adaption of
fundamental components to
meet special needs
System Calibration
Transducers and Electrodes

Suggested Problems
Analog to digical Converters
Adaptation of Recording Devices

APPENDIX M. ACTIVE PROGRAMS AND ASSOCIATIONS

APPENDIX M

ACTIVE PROGRAMS AND ASSOCIATIONS

Interest in upgrading of service to biomedical equipment in hospitals has been greatly encouraged by many professional medical and engineering organizations. Below are descriptions of how several regional medical programs and professional societies and organizations are currently involved in this area.

WASHINGTON/ALASKA REGIONAL MEDICAL PROGRAM
238 UNIVERSITY DISTRICT BUILDING, SEATTLE, WASHINGTON 98105

The Washington/Alaska Regional Medical Program is involved in two projects which directly pertain to biomedical equipment. Both projects seem directly linked to a hospital survey which they completed, indicating that twenty-one of the twenty-five hospitals in the sample had a variety of safety hazards stemming from their biomedical equipment.

The first project involved courses which are given to doctors and nurses on electrical safety in hospitals, especially in ICU/CCU areas. The courses emphasize various kinds of safety problems and how to prevent catastrophes. The courses for nurses are given in thirteen sub-regions through local community colleges, and over 1,000 nurses a year are exposed to the course, which for them consists of a two-hour lecture. The courses for doctors are five days in length, usually involve twenty-five doctors, and are given four times a year in Seattle.

The second project involves the evaluation of medical equipment and medical equipment systems from the point of view of safe, efficient use. This evaluation process allows RMP to advice hospitals in their region on what kinds of equipment to buy, and what kinds to avoid.

INTERMOUNTAIN REGIONAL MEDICAL PROGRAM
50 NORTH MEDICAL DRIVE, SALT LAKE CITY, UTAH 84117

The Intermountain Regional Medical Program, covering Utah, parts of Idaho, Montana, Wyoming, Colorado, and Nevada, has been involved in assisting hospitals in setting up coronary care facilities. As hospitals started to purchase medical equipment necessary for these facilities, it became obvious that they needed in their employ someone who knew more about the equipment. RMP identified an individual in each hospital who had a special interest in coronary care and maintenance of equipment. These individuals (totalling almost 150, consisting of maintenance personnel, lab technicians and hospital administrators) were provided with an intensive basic electronics course, so that they could handle some of the problems they had with monitoring equipment. Two five-day courses and many two-day courses have been given. The courses stressed safety factors in the use of equipment as well as maintenance and diagnosis of problem techniques. "Graduates" of these courses are now prepared to work with doctors and nurses in operating and, for minor problems, repairing the equipment. As a result of the course, many individuals have started to try to acquire more knowledge in the field through correspondence courses, night school classes, and from manufacturers. Plans for taking the two-day course around to sections of this RMP region are now being acted upon.

The next step will be to hold seminars between engineers from manufacturing houses and hospital staff who work with their equipment. The object would be to have the engineer take the entire piece of equipment apart, to demonstrate where problems most frequently occur.

These courses, in conjunction with a bi-annual Medical Electronics Technician bulletin, have had a strong impact on hospitals in this sparsely populated area of the country. Persons who have taken the courses are starting not only to work very closely, and talk intelligently, with the rest of the hospital staff, but also to work closely with outside service technicians allowing for frequent "telephone repairs," thereby cutting down on hospital repair costs.

NORTHERN CALIFORNIA REGIONAL MEDICAL PROGRAM (AREA I)
WARD 35 SOLARIUM, 22nd AND POTRERO AVENUE
SAN FRANCISCO, CALIFORNIA 94110

The Regional Medical Program covering the San Francisco area is presently funding a project concerned with the safety of various kinds of medical equipment. Dave McKinney, functioning as the electronics consultant to RMP-Area I, is making a case study of the San Francisco General Hospital, evaluating all of its patient-care equipment, with the intent

of making the information available to all California hospitals. He has had both the hospital staff and outside servicemen (from manufacturers and suppliers) keep records on all the repairs and related problems encountered on individual items of equipment. In addition to increasing communication and understanding between the hospital staff and outside servicemen (i.e., maintaining an interface between the physician and the manufacturer), the keeping of these records will provide valuable information on the cost of upkeep, efficiency and durability of a range of types of medical equipment. On the basis of these records, accurate and useful recommendations for purchase of medical equipment in the future will be possible. These records also indicate in what areas seminars on the safe, efficient use of medical equipment are necessary. It is the hope that by carefully following the functioning of a wide variety of kinds of medical equipment over a period of time, recommendations for safety standards will be able to be administered through the California Hospital Association.

In addition to closely studying use and misuse of specific items of medical equipment, this RMP project provides a variety of kinds of training for hospital staff. This includes:

(a) a one-week course for MD's, introducing them to new pieces of sophisticated research equipment, and talking about the kinds of problems they might have with the equipment, including at least half a day on safety;

(b) courses for nurses: (1) a basic coronary care course with some time spent on equipment use and safety; (2) an advanced course on cardiogomy, introducing various computer concepts;

(c) lectures for general hospital staff on equipment operation and safety;

(d) 2 1/2 week orientation for nursing administration, including how to advise their nursing staff on equipment problems.

MINNESOTA HEART ASSOCIATION
4701 WEST 77th STREET, EDINA, MINNESOTA 55435

A group of ten cardiologists in the Minnesota Heart Association received a grant from the Northland Regional Medical Program for a multi-disciplined program to improve coronary care in hospitals. Their program includes doctors,

nurses, administrators, and BMET's. The MHA currently has representatives from all four groups who act as consultants to any hospital who requests help in any area. There has been considerable interest and support throughout the State of Minnesota.

The MHA also runs conferences in an effort to improve communications and service in the state among the four above mentioned groups. Under this three-year grant there are plans to hold twoto three conferences per year specifically for the Biomedical Electronics Technician, drawing these men from hospitals all over the state for one day sessions. The first conference was held on January 16, 1970, and the second is scheduled for May 20. Following is a description of those attending the first session.

> "The first Minnesota Conference ever held for Medical Electronic Technicians got under way January 16, with twenty-one men attending from out-state Minnesota, and thirteen from the Twin Cities. A breakdown in the nature of their employment shows that only six men work full time as medical electronic technicians; twenty-two are classified as being in the engineering department, devoting only part time to medical electronics work; four are paramedical men who have the added responsibility of medical electronics technicians, and two are employed outside the hospitals and come in on a consultation basis as needed."

The January 16 seminar included the following topics:

1. Coronary Care 1970 and Your Role in the Medical Team
2. Basics of Cardiac Monitoring Systems
3. Other Medical Electronic Equipment: Rate Meter, Alarms, Defibrillator, Memory Loop
4. Special Electronic Considerations in an ICCU
5. Pacemakers and Their Hazards
6. How to Recognize and Correct Common Malfunctions
7. Preventive Maintenance Necessary for Utility and Safety
8. Problem Solving Workshops and Panel Discussions

Meetings involve manufacturers of different new products of interest to the membership, from the safe use of medical and biomedical equipment to proper paints for hospital use.

The Association also sponsors "brush-up" courses in such subjects as powerplant operations, medical equipment use and repair, and diathermy, in conjunction with several local schools.

CALIFORNIA HOSPITAL ENGINEERS ASSOCIATION
11th AND L BUILDING, SUITE 900,
SACRAMENTO, CALIFORNIA 95814

The California Hospital Engineers Association is currently holding monthly meetings of their membership which is primarily administrative engineers. Their current goal is electrical safety, trying to promote in-house consciousness of the hazards involved in the increasing amount of instrumentation in the hospital. They are trying to up-grade the position of the biomedical engineer; to educate hospitals on the cost of in-house as opposed to contract maintenance of their instruments, and the need for preventive maintenance.

AMERICAN MEDICAL ASSOCIATION
535 NORTH DEARBORN, CHICAGO, ILLINOIS 60610

According to the ASHE, the AMA is currently not organizing any society concerned specifically with the BMET or hospital engineering. However, many doctors within the AMA are aware of the problem of maintenance of medical instruments and have published papers concerning this in the AMA Journal and other publications in specialized areas.

ASSOCIATION FOR THE ADVANCEMENT OF MEDICAL INSTRUMENTATION
9650 ROCKVILLE PIKE, BETHESDA, MARYLAND 20014

AAMI is a national organization whose principal function is to establish uniform standards for instruments acceptable to both the medical profession and industry. There are 1-2,000 members, including doctors, engineers, and manufacturers. They hold an annual symposium on the use of instrumentation in specific areas of medicine. Currently AAMI is developing a certification program for the BMET, with the cooperation of TERC, the AMA, and industrial manufacturers.

INSTRUMENT SOCIETY OF AMERICA
KOSSMAN BUILDING, PITTSBURGH, PENNSYLVANIA

The ISA has a biomedical division, with approximately 200-250 members, primarily engineers. The division is interested in aspects of instrumentation associated with medical (diagnostic and therapeutic) and biological equipment. The division has its own annual meeting (this Spring it will be held in Denver in conjunction with the Rocky Mountain Engineering Group), and in addition, plans several sessions for the annual ISA conference. They have a quarterly newsletter which reflects their interests in instrumentation, in involving engineers and doctors in a common cause, and in the safety practices of biomedical instrumentation.

The ISA has an educational service which provides short courses (one-five days) on a number of different topics, and the biomedical division is anxious to run a few of these in their field.

INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS
345 EAST 47th STREET, NEW YORK, NEW YORK 10017

IEEE has 31 different societies in technical areas of which the Biomedical Engineering Society, an attempt to bring engineering and medical professionals together, is one. There are 5000 members in chapters across the country. Members are engineers from hospitals, universities and industry - ranging from student members to potential "Nobel prize winners." The chapters are very autonomous, sometimes receiving ideas and materials (i.e., films, tapes of interesting conferences, printed reports) from the IEEE office. The emphasis is changing from the theoretical research to practical applications - for example, how a known tool like computers can be used in hospitals in a variety of ways.

The JCEMB (Joint Conference of Engineers in Medicine and Biology) was a conference of people from IEEE, ISA, Mechanical Engineers and Chemical Engineers, which met yearly. At the 1969 meeting (which was also an international conference) in Chicago, it was decided to dissolve the JCEMB and form the AEMB (Alliance for Engineers in Medicine and Biology) to give the Biomedical people equal standing.

ALLIANCE OF ENGINEERS IN MEDICINE AND BIOLOGY
NATIONAL INSTITUTE OF HEALTH, WASHINGTON, D. C.

AEMB will have its first meeting in November 1970, and

begin where JCEMB finished, with presentations of reports on scientific investigation. The big change is a growth from four to eighteen societies in its membership, and the first order of business is "getting them all to feel comfortable with each other."

AMERICAN SOCIETY FOR QUALITY CONTROL, BIOMEDICAL TECHNICAL COMMITTEE
7 LAKESIDE OFFICE PARK
WAKEFIELD, MASSACHUSETTS 01880

The ASQC is a professional engineering society of over 23,000 members. Their emphasis is on quality progress by laboratory, and management personnel -- anyone interested in quality control. About two and a half years ago the ASQC developed a Biomedical Steering Committee of eight members to ascertain whether the ASQC could contribute to the medical community. Their report stated three areas in which it could: Instrumentation, Statistical Techniques, and Health Care Services. The Steering Committee was turned into a Technical Committee of unlimited membership to begin work in the three areas. As this specific concern with the biomedical field is new to the ASQC, this is not yet a full division of the Society.

The work so far has been theoretical in an effort to develop a professional matrix allowing communication between medical, engineering, and manufacturing personnel. The committee sees a technician such as the BMET as a solution to many of the problems it has encountered between the medical and engineering fields. Currently members are lecturing and writing articles and books to disseminate the information. In instrumentation they are working closely with AAMI.

JOINT COMMISSION ON HOSPITAL ACCREDITATION
MONTEFIORE HOSPITAL, 111 EAST 210th STREET
BRONX, NEW YORK

The Joint Commission on Hospital Accreditation includes the College of Surgeons, the College of Physicians, the AMA, and the AHA, which issues guidelines for hospitals in three areas: physical plant, staffing qualification, and "moral fiber." These guidelines can only be enforced indirectly-- without the Commission Inspectors' approval, a hospital cannot receive Blue Cross funds.

A current emphasis of the Commission is on the upgrading of safety in patient care through attention to electrical

safety factors and preventive maintenance. The upgrading of service to biomedical equipment is a natural outcome of this emphasis and the Commission has tried to suggest that hospitals should have on staff or engage consultants who are equipment specialists and will see to the enforcement of safety practices involving the equipment. However, this is best enforced by the more powerful AAMI with whom the Commission works closely. AAMI is in a position to institute certification of Biomedical Equipment Technicians when the procedures for certification can be agreed upon by all concerned.

MASSACHUSETTS HOSPITAL ASSOCIATION
225 FRANKLIN STREET
BOSTON, MASSACHUSETTS 02110

The Massachusetts Hospital Association has been interested in the safe, effective use of medical equipment in hospitals. To this end they have developed a grant proposal, presently in search of funds, which covers a four-part program:

1. to provide consultation by a hospital association-employed bio-engineer to hospitals on the use and repair of medical equipment;

2. to distribute on a regular basis a newsletter concerned with the hazards involved in using certain kinds of medical equipment;

3. to test the feasibility of the association's providing a service which would screen equipment for safety;

4. to maintain a central reporting service which will keep records on the type and frequency of breakdown of pieces of medical equipment in the areas' hospitals and to distribute this information to hospitals.

NATIONAL ACADEMY OF ENGINEERING
COMMITTEE ON THE INTERPLAY OF ENGINEERING
WITH BIOLOGY AND MEDICINE
WASHINGTON, D.C.

The committee, with a grant of money from NIH, is working on a two phase research project. Several regions of the country are being studied independently by university staff in those regions to gather the following information: Phase I, How can the university work with health services in order to bring better health care to the entire community; Phase II, how can industry be involved in order to produce better health services. Some of the regions included in this study are becoming interested in biomedical instrumentation and its correlant problems.

APPENDIX N. AREAS FOR FURTHER INVESTIGATION

APPENDIX N

AREAS FOR FURTHER INVESTIGATION

Perhaps one of the greatest values of any study lies in the questions which it raises for further investigation. We have attempted to clarify the broad range of types of technicians in the field and the increasing importance of BMET's to the present and future health care delivery system. Hopefully, this picture will be convincing enough to stimulate interest among employers and educators, both present and potential - those people who have the power to open up positions in their institutions and to train BMET's in the skills necessary to fill them. We feel that this report suggests several areas for further study of great importance to these people.

The most immediate way to evaluate the need for the BMET is to look at the organization of biomedical equipment maintenance in the hospital in order to gain a realistic idea of how much medical instrumentation maintenance costs. Here are some of the questions that such a study might hope to answer:

1. Does having an in-house BMET save a hospital money?

2. How much is spent on new equipment every year and how much is spent on the maintenance and repair of this equipment.

3. Through what channels is equipment purchased and repaired: trough each department and its supervisory MD's? through purchasing? through the administration? Should both repair and purchase be handled through the same channels?

4. Who is and should be performing repairs on biomedical equipment: equipment operators in the departments? outside manufacturers and/or contract maintenance companies? engineering and/or maintenance staff? specialized repair technicians?

5. What kinds of repair services are most accessible to the hospital?

6. Is there anywhere in the hospital a complete inventory of biomedical equipment, its original cost, its age, the number and cost of repairs to it? And what uses are made of this inventory?

Of interest also would be a comparison of these facts for urban and rural areas: areas where manufacturers service offices are located and where there is little or no service close at hand. From this information could be derived the kinds of repair systems that could most effectively be utilized by different hospitals. For example: large staffs of specialized BMET's for large hospital complexes; shared pools of BMET's for smaller or specialized hospitals in one area; equipment operators trained to do all but the most major repairs, for certain departments like labs and Inhalation Therapy; and generalized BMET's to work in areas where the manufacturer is close at hand.

A second important study might be of the manufacturers' policy and new trends in the handling of maintenance on their equipment. It will be important to considerations for training programs as well as the BMET's role to have information on:

1. How widely will sealed components/modules be used and how will they affect the need for and the required skills of repair personnel?

2. Will the leasing of equipment to hospitals turn much of the repair burden over to the manufacturer? And if so, will BMET's in the future most naturally and practically be employed directly by the manufacturer rather than hospitals?

3. How will warantees and the policy toward handing out circuit diagrams and manuals with the sale of equipment effect the training of in-house BMET's?

A third important area for study is the role of the BMET in relation to doctors, engineers, and other paramedicals. An often heard complaint in our study was that BMET's were not sufficiently respected by the rest of the medical staff--either because of incompetence on the part of the technician or a lack of understanding of his role. Perhaps a common understanding could be reached by looking at the following questions:

1. What kinds of training could be provided in-house, or perhaps during their education, to alert MD's and paramedicals to the most efficient utilization of their equipment and of this technician specialized in the maintenance of their equipment?

2. What method of organization within the hospital structure would most efficiently utilize the different areas of competence of the MD, the engineer, the paramedical, and the BMET in improving biomedical instrumentation?

3. Can the whole problem of implementing electrical safety codes be used to unite the four groups into a working system?

4. How can the professional status of the BMET be raised? Is certification necessary?

One further question in relation to all three areas outlined above is how do trade unions effect the repair of biomedical equipment in hospitals, and may their effect change in the future?

In addition to problems of practical interest to people directly in the field, there are some more academic questions raised by a study if a new and growing technology and preparations to train manpower for it. Some areas are of particular interest to TERC because of its role in providing a communication between the technology as it is emerging and the institutions interested in providing training for it. Currently there are three problems being studied by TERC staff. The first involves how to evaluate training programs. What kinds of evaluative tools can be developed, and can the same tools be used for both existing and proposed programs? What criteria can be established for measuring the effectiveness of a training program?

The second area involves the specific skills that are needed by a BMET. What should the specific focuses within the general areas (electronics, mechanics, physiology, etc.) be in a training program? To what degree does the BMET need to understand each of these disciplines? What are the smallest components of each piece of biomedical equipment that should be taught to the students?

The third area involves trying to get educators and employers of BMET's together in order to share information on the field. Only through this kind of interactive network can

there be an assurance that training programs are producing the numbers and kinds of technicians for which there is a market.[1] The feasibility, as well as possible channels for this communication, are now being studied.

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1. See Appendix C for a preliminary discussion of the findings in this area.

APPENDIX O. MANPOWER METHODOLOGY

APPENDIX 0

MANPOWER METHODOLOGY

Model

Under growth conditions, an increase in demand for technician manpower arises from the increased needs of existing employers and also from the needs of new employers which are entering the job market for the first time.

We have taken the existing employers to be those which employed technicians in 1970, and we have assumed that all of them will continue to employ BMET's throughout the period of our projections. We have calculated their future demand for technicians by simply multiplying the number of companies (a constant from 1970 onwards) by an annually increasing value for the number of technicians employed for each year 1970 through 1975.

For new employers, we have assumed that in the first year they will employ one technician. In subsequent years their increase in needs will grow at the same rate at which existing companies add technicians to their staff.

The model used has been derived as follows:

Let $E_{t,i}$ = Number of employers of type (size) i, in year t

$DE_{t,i}$ = Number of new employers of type (size) i, in year t

$A_{t,i}$ = Average number of BMET's per employer of type (size) i in year t

t = 0,1,2,3,4,5; where t = 0 = 1970

The number of technicians in:

1970 is $N_{0,i} = E_{-1,i}A_{0,i} + DE_{0,i}.1$

1971 is $N_{1,i} = E_{-1,i}A_{1,i} + DE_{0,i}[1 + (A_{1,i} - A_{0,i}] + DE_{1,i}$

1972 is $N_{2,i} = E_{-1,i}A_{2,i} + DE_{0,i}[1 + (A_{2,i} - A_{0,i})] + DE_{1,i}$
$\cdot[1 + (A_{2,i} - A_{1,i})] + DE_{2,i}$

Alternatively, by subtracting the relationship for 1971 from that for 1972 we have:

$$N_{2,i} = N_{1,i} + (E_{-1,i} + DE_{0,i} + DE_{1,i})(A_{2,i} - A_{1,i}) + DE_{2,i}$$

Note; $E_{1,i} = E_{-1,i} + DE_{0,i} + DE_{1,i}$

Hence the general relationship for the year (1970 + t) is:

$$N_{t,i} = N_{t-1,i} + E_{t-1,i}(A_{t,i} - A_{t-1,i}) + DE_{t,i}$$

This relationship has been used for both hospitals and companies. Four hospital size ranges were selected, but companies were treated as a single group.

Hospital Employers

Though 197 hospital and research institute employers were interviewed, not all the data were used in developing the manpower estimates. Those hospitals and research institutes which reported abnormally large numbers of BMET's (greater than twenty) were eliminated before making the manpower projections. We also eliminated all hospitals with less than 200 beds.

Hospital Group

Hospitals in the sample were categorized by the following bed sizes: (a) 200-400, (b) 401-600, (c) 601-1000, and (d) greater than 1000. We have assumed that for each category the hospitals in our sample were representative of all the hospitals in the size range.

Our data indicated that about 50% of all hospitals above 200 beds employ BMET's, a value which was confirmed by the mail survey already reported in Appendix E. However, for the individual size categories, we have little data on the percentage of hospitals who employ BMET's. To an extent we have arbitrarily assumed the breakdown shown in Table XIX.

TABLE XIX

	Bed Size Ranges			
	200-400	401-600	600-1000	Over 1000
Total Number of Hospitals, AHA Guide	1080	360	190	305
Percentage of Hospitals employing BMET's in 1970	40 ± 5%	50 ± 5%	60 ± 5%	70 ± 5%
Number of Hospitals in our Sample	54	38	18	16

Growth in Number of Hospitals

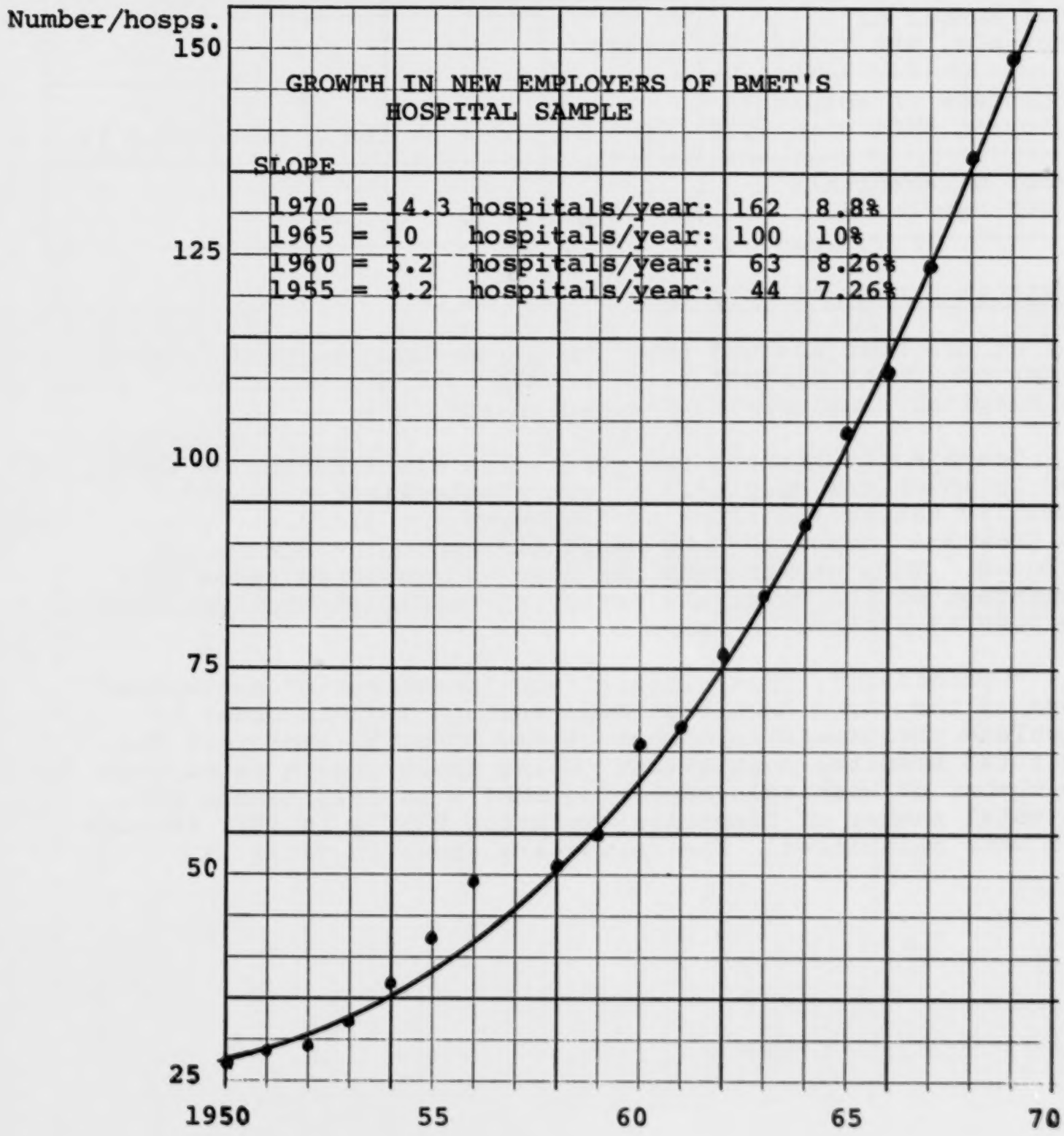
It has been assumed that the percentage growth in number of new employers of BMET's is the same for all bed sizes. Hence the hospital data were aggregated in this case.

Graph A illustrates the cumulative distribution of the year in which the hospitals in our sample first employed a BMET. By taking the slope of the curve for different years, the growth in number of new hospitals employing BMET's can be found. This growth rate has been expressed in terms of a percentage of the hospitals employing BMET's in that year and the results plotted in Graph B.

"Optimistic", "Most likely" and "pessimistic" extrapolations of the curve have been made through 1975 in order to calculate the growth in number of new hospital employers for the total hospital population. Using these growth rates, and the number of hospitals employing BMET's in 1970 (Table XX), the total number of hospitals employing BMET's in 1971 through 1975 were calculated. The values are shown in Table XX.

GRAPH A

CUMMULATIVE DISTRIBUTION OF FIRST YEAR IN WHICH HOSPITALS EMPLOYED BMET'S



GRAPH B

PERCENTAGE GROWTH IN NEW HOSPITALS EMPLOYING BMET'S

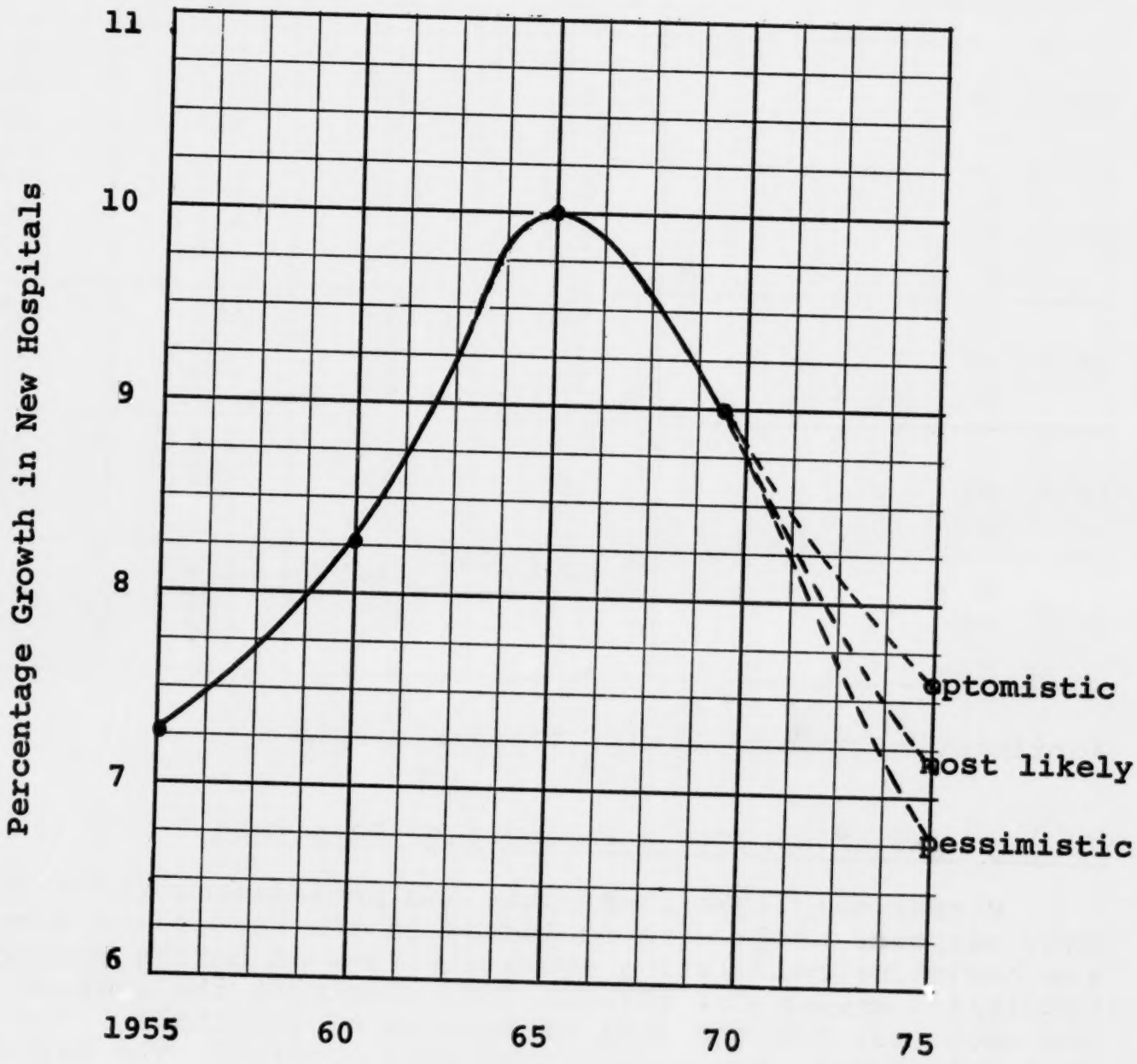


TABLE XX

Number of Hospitals Employing BMET's

		Bed Size Range			
		200-400	401-600	601-1000	Over 1000
1970	o*	450	189	120	220
	ml**	430	180	115	210
	p***	410	181	110	200
1971	o	490	205	130	239
	ml	467	195	125	228
	p	444	185	119	216
1972	o	532	222	141	258
	ml	506	210	135	246
	p	480	199	128	233
1973	o	576	239	152	279
	ml	546	225	145	265
	p	516	214	138	250
1974	o	621	258	164	300
	ml	589	242	155	284
	p	555	229	148	267
1975	o	669	278	176	305
	ml	632	260	167	305
	p	595	244	158	285

*optimistic, **most likely, ***pessimistic

Average Number of BMET's Employed by Hospitals

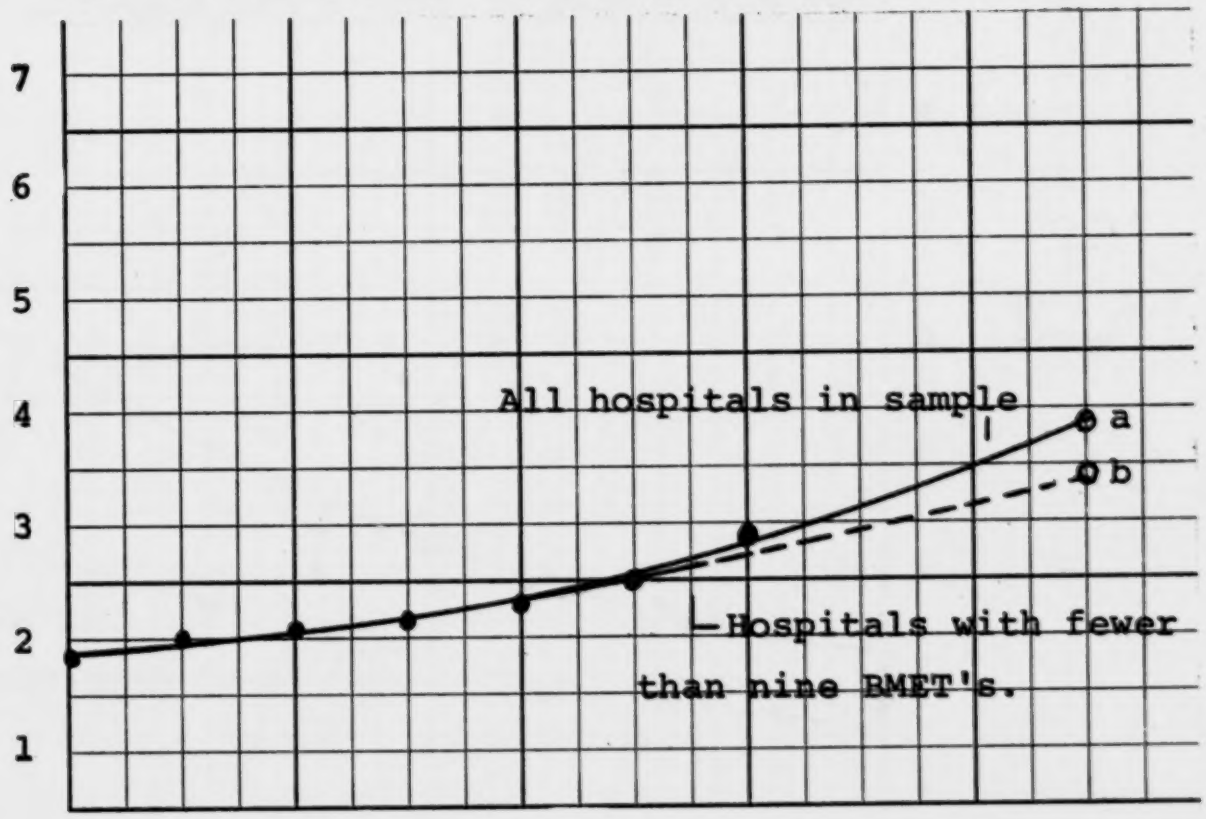
Historical (1966-1969) data and projections (1970-75) of BMET manpower needs were collected in the survey and have formed the basis for calculating average values of BMET's employed by hospitals. Graphs C-1 through C-4 illustrate the average values for each year for the four categories of hospitals. For all four categories, two curves have been plotted. The highest value curve (curve (a)) in each case is based on the total hospitals within the sample. The lowest value curve (curve (b)) in each case is based on eliminating those few hospitals

GRAPHS C-1, C-2

AVERAGE NUMBER OF BMET'S PER HOSPITAL

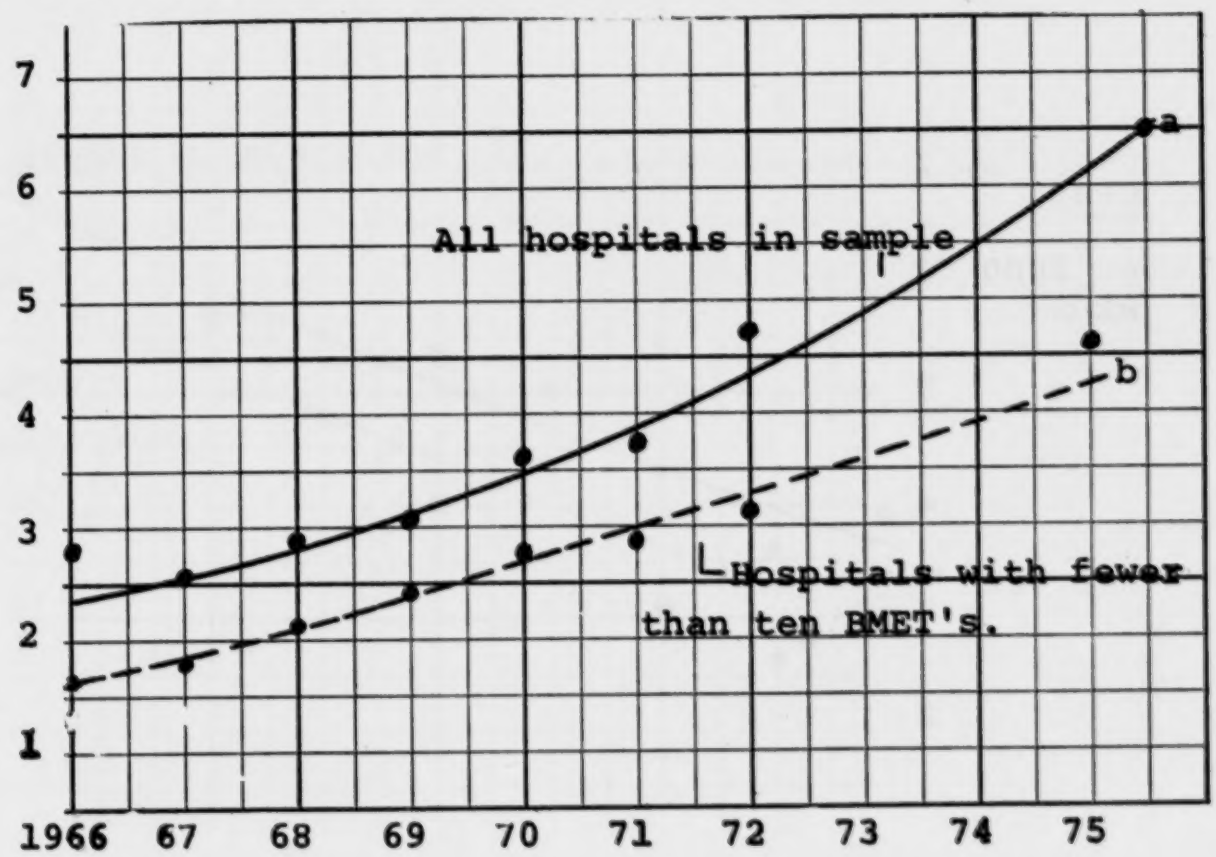
C-1

200-400 BEDS



C-2

401-600 BEDS

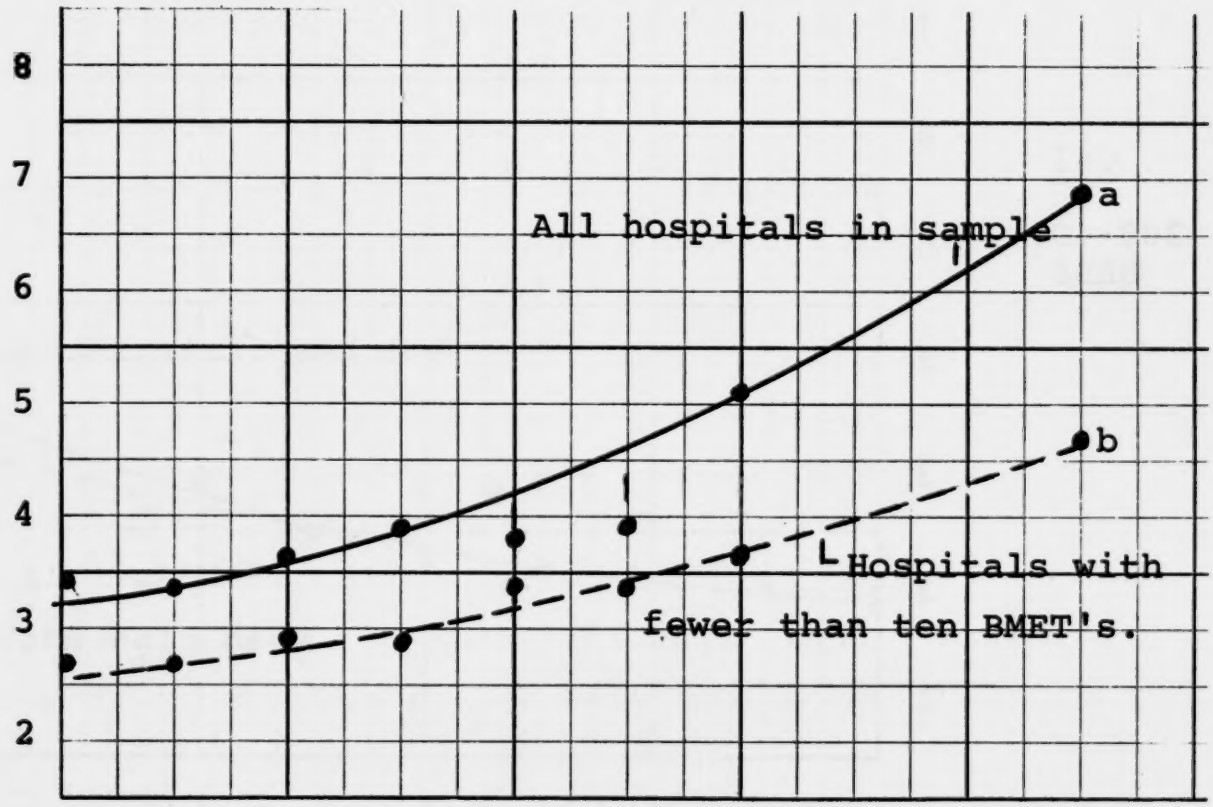


GRAPHS C-3, C-4

AVERAGE NUMBER OF BMET'S PER HOSPITAL

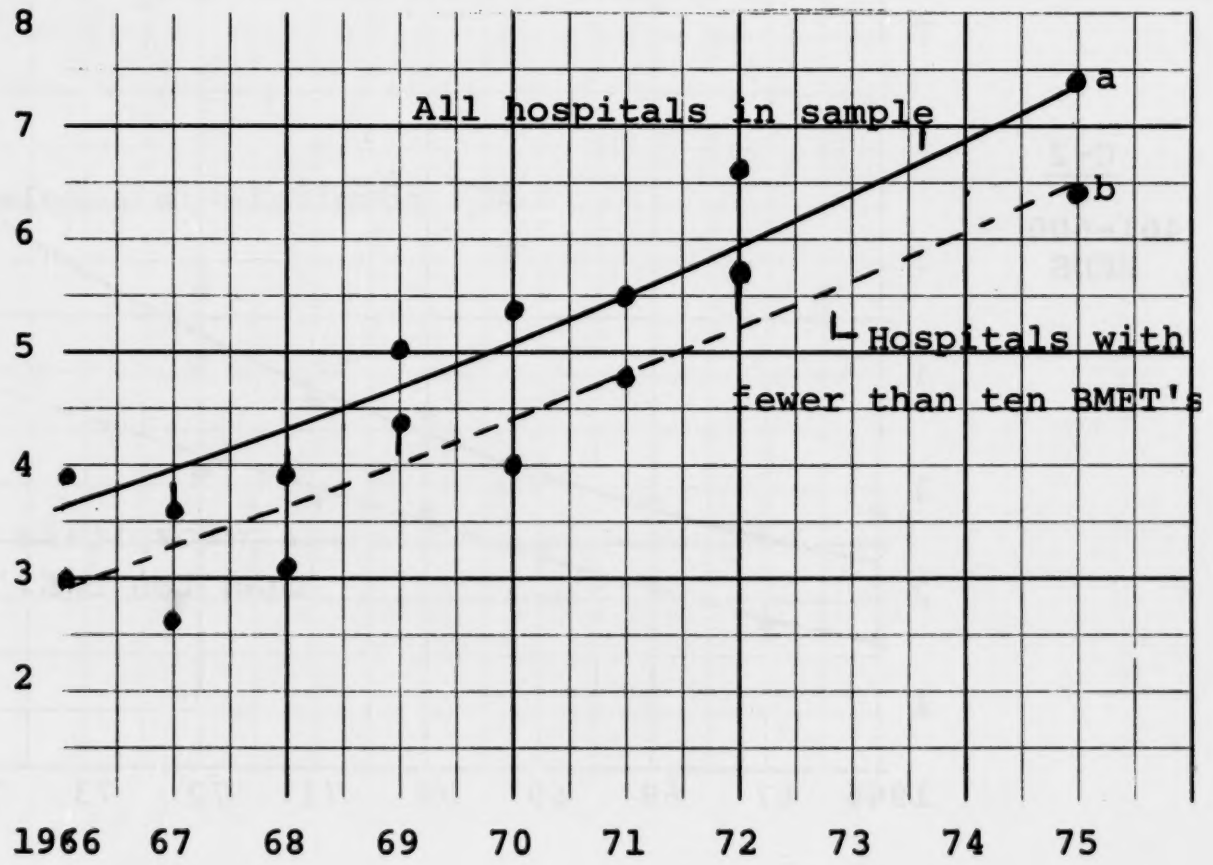
C-3

601-1000 BEDS



C-4

Over 1000 BEDS



which reported values considerably greater than the majority.

A. Hospitals (200-400)

For this size of hospital we have taken the optimistic value for the average number of technicians to be given by curve (b) in Graph C-1. We have a pessimistic growth rate to be given by the extrapolation of the historical growth pattern. We believe the most likely average value will lie at some intermediate point which, in our calculations, we have taken to be the mid-point values.

B. Hospital Sizes (401-600, 601-1000; over 1000)

For each of these sizes we have assumed optimistic values of the average number of BMET's to be given by curve (a) in Figures C-2, C-3 and C-4 respectively. Further we have assumed pessimistic values to be given by the curve (b) which was computed by eliminating those few hospitals reporting more than ten BMET's (sizes 400-1000) and more than fourteen BMET's (size over 1000). We believe the most likely average number of BMET's will lie in the middle of these ranges.

Calculation of Manpower Needed by Hospitals

Using the model developed earlier, the data in Table XX showing the number of hospitals, and the Graphs C-1 through C-4 showing the average number of technicians, we have calculated the total number of BMET's employed by hospitals through 1975. The values are shown in Table XXI.

TABLE XXI

Total Number of BMET's Employed in Hospitals

		Bed Size Range				
		200-400	401-600	601-1000	Over 1000	Total
1970	o	1020	640	500	1140	3300
	ml	960	550	420	1100	3000
	p	910	470	350	960	2700
1971	o	1160	750	560	1370	3800
	ml	1070	630	470	1210	3400
	p	980	510	390	1070	2900
1972	o	1320	880	640	1490	4300
	ml	1180	730	520	1330	3800
	p	1040	590	430	1180	3200
1973	o	1510	1020	720	1620	4900
	ml	1310	840	590	1450	4200
	p	1120	670	480	1290	3600
1974	o	1700	1200	820	1750	5500
	ml	1440	980	670	1580	4700
	p	1200	780	530	1420	3900
1975	o	1900	1380	940	1880	6100
	ml	1580	1120	760	1720	5180
	p	1280	880	590	1550	4300

Company Employers

The three major types of companies in the biomedical equipment field which employ BMET's are manufacturers, distributors (supply houses) and contract maintenance. For many companies the biomedical equipment field is a small part of their business. Furthermore it is not uncommon to find companies with operations in more than one area of production, distribution (their own plus other manufacturers' equipment), and contract maintenance. Because of this fragmented and ill defined structure in the field, classification and stratification of companies proved unrewarding. We have assumed that our sample was purely random and representative of all types of companies which employ BMET's.

Total Number of Companies

Nowhere is the fragmentation of the field more apparent than in estimations of the total number of firms which have significant operations in the biomedical field, and thus by implication are employers of BMET's. Depending on how the industry is defined, the number of manufacturers has been estimated to range from 400 to 2400 firms. Adding supply houses and contract maintenance companies may well raise the number of companies by another 500 to 1000. But as characteristic of most fields, a small number of firms account for a large volume of sales. For example, in 1968 A. D. Little reported that the top fifteen companies accounted for over half the total industry sales. A consequence of this is that the gross sales of most companies was less than $500,000 and for many less than $100,000. In 1966 a survey by the Institute of Science and Technology at the University of Michigan[1] found that of 324 responses only 104 (32%) reported sales greater than $500,000, and 78 (24%) had sales in excess of one million dollars.

For the purpose of predicting the manpower requirements we are assuming that all companies with sales less than about $500,000 have no BMET's. Furthermore we are assuming that the percentage of firms with sales greater than $500,000 has grown from 32 per cent in 1966 to 35 per cent today. Taking Abele, Berkeley and Post's estimated total number of 1500 manufacturers in the medical instrumentation field and adding a further 300 for supply houses, we have assumed a total population of manufacturers and supply houses to be 1800. Hence we have taken the total number of manufacturers and supply houses which employ BMET's to be 630.

Since contract maintenance companies in the biomedical equipment field of necessity employ BMET's we have estimated that there are about seventy in existence today.

In summary, we have taken the total population of companies which employ BMET's to be 700. To explore the implications of errors in our assumptions we have taken upper and low bounds on the number of BMET-employing companies to be 800 and 600 respectively.

Growth in New Companies Employing BMET's

The cumulative distribution for the first year in which the companies first hired a BMET is shown in Graph D. The data strongly suggest that the annual increase in number of

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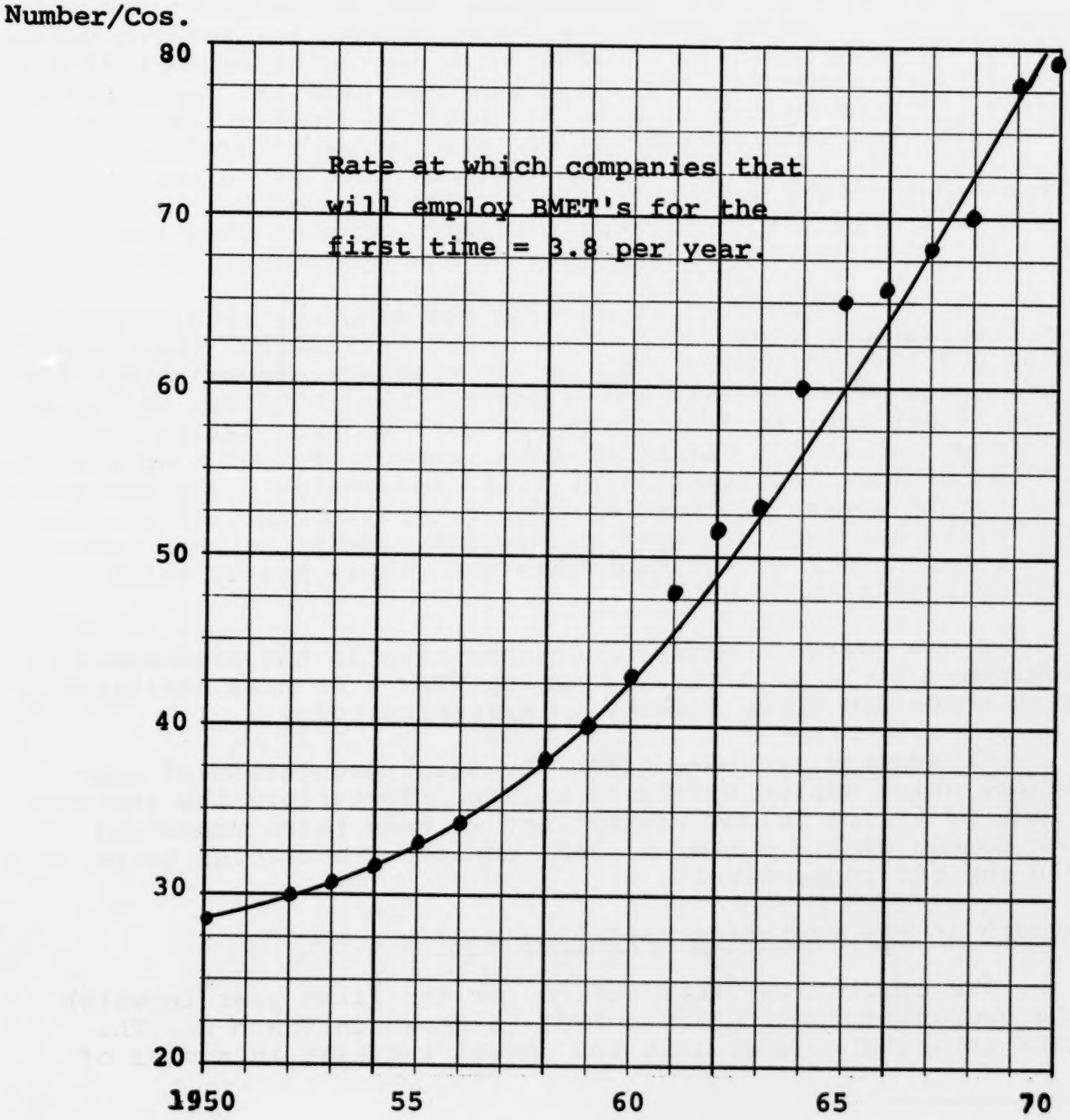
1. See Bibliography, Appendix Q.

GRAPH D

GROWTH IN NEW EMPLOYERS OF BMET'S
COMPANY SAMPLE



new companies which employ BMET's is constant at four companies per year. Extrapolating this to the total population we have taken the annual increases in the number of new companies to be 32, 28 and 24 for the upper, most likely and lower limits respectively.

Average Number of BMET's Employed per Company

Historical data (1966-1969) and estimates for the future (1970-75) were collected in the survey and form the basis on which the average number of BMET's were calculated. Graph E illustrates the values obtained with curve (a) derived from the total sample and curve (b) derived by screening out those few companies who estimated needs considerably greater than the majority. It should be noted that we have treated the field offices of the large companies such as Hewlett-Packard, Beckman, G.E., etc., as companies in their own right.

A "most likely" average value for the number of technicians employed per company was taken to be an average of the two curves.

Calculations of Manpower Requirements

Using the values for the total number of companies, annual rates of establishment of new companies and the average number of BMET's, estimates of the manpower requirements have been calculated using the model previously described. The results are given in Table XXII which also shows the summary values for the hospitals, and for the aggregate of hospitals and companies.

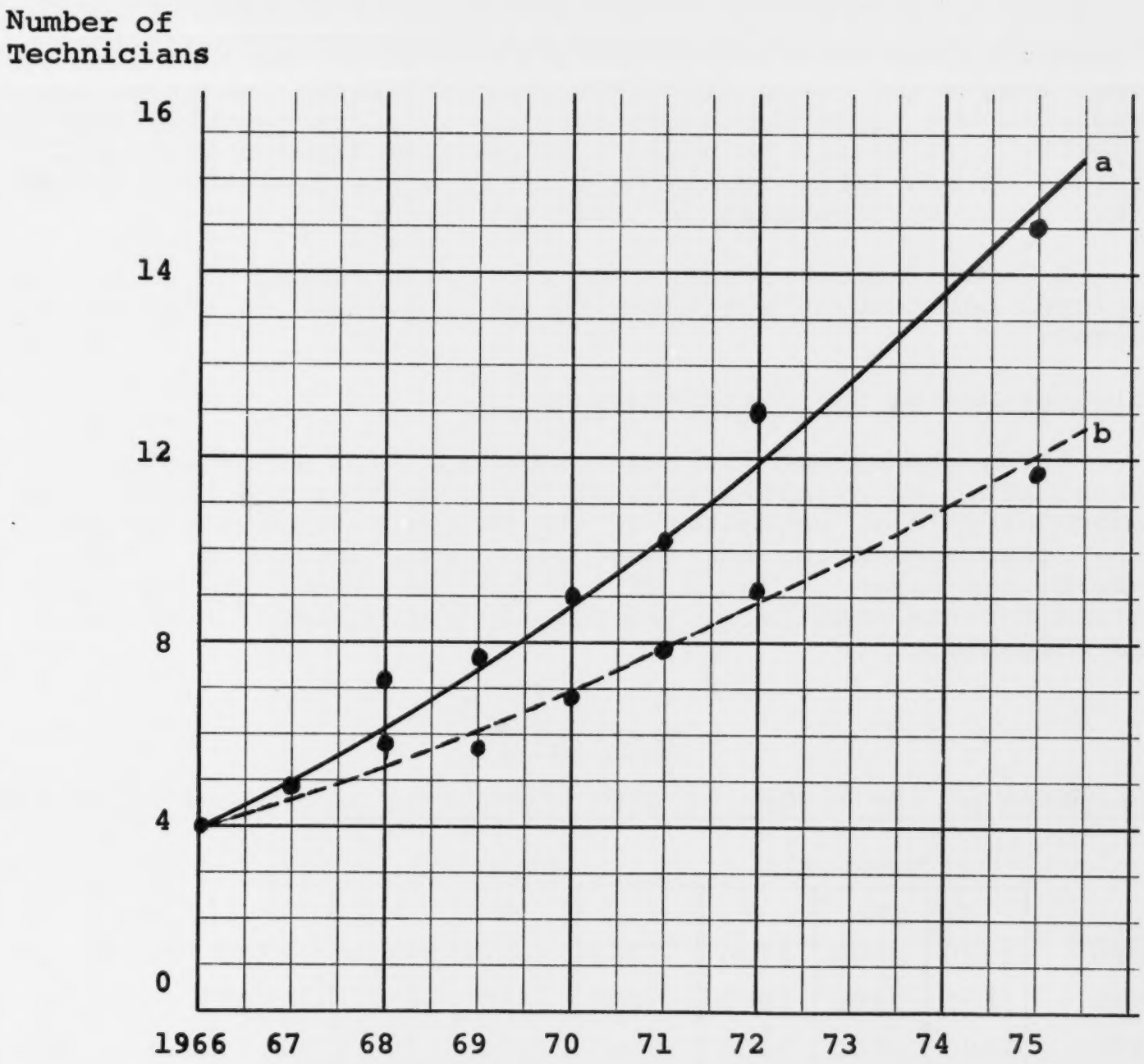
TABLE XXII

Estimates of the Number of BMET's who will be Employed 1970-1975

	Hospitals			Companies			Total		
	o	ml	p	o	ml	p	o	ml	p
1970	3300	3000	2700	7200	5600	4200	10500	8600	7100
1971	3800	3400	2900	8400	6500	4800	12200	9900	7700
1972	4300	3800	3200	9800	7600	5600	14100	11400	8800
1973	4900	4200	3600	11400	8700	6400	16300	12900	10000
1974	5500	4700	3900	13200	9900	7200	18700	14600	11000
1975	6100	5180	4300	15200	11300	8000	21300	16480	12300

GRAPH E

AVERAGE NUMBER OF TECHNICIANS PER COMPANY



Consistency of Manpower Projections

As a check on our projections of the number of BMET's employed in any year, we have compared them to the dollar volume of medical equipment in use in that same year. This is a very gross measure of consistency and should be treated as such.

We have taken the total sales of medical instrumentation from the A. D. Little April 1969 report which covered the period 1968-1973. In addition we have assumed that the total sales of medical instruments in 1975 will be 1.1 billion dollars, which is a compromise between an extrapolation of A. D. Little's figures and those cited in a recent survey report by D.M.S.

Assuming the life of an instrument to be five years, the total dollar volume of equipment in use can easily be calculated by summing the sales for the previous five years. On this basis, the total dollar volume of equipment in use in 1970-75 is shown in Table XXIII. These figures do not take into account depreciation or inflation since we are not concerned with estimated market value of equipment in use.

The ratio of total dollar value of medical equipment in use and the total number of BMET's employed for each year 1970 through 1975 is also shown in Table XXIII. The relatively constant value of about $260,000 of medical instrumentation per technician through the period of our estimates is taken to mean that our projected rate of growth is consistent with growth rate in sales of medical instruments. We attach no significance to the value of medical instrumentation per technician.

TABLE XXIII

	1970	1971	1972	1973	1974	1975
Total Dollar Volume of Medical Instruments (Millions)	2291	2585	2920	3280	3710	4320
Total Number of BMET's (Most Likely Estimates)	8600	9900	11400	12900	14600	16840
Dollars of Medical Equipment per Technician (1000's)	266	261	256	254	254	256

Number of BMET's to be Prepared

Because of the turnover of technicians out of the field due to retirements, deaths, disillusionment with the field, etc., there is a need to prepare more technicians than the number which will satisfy newly budgeted positions.

Our data indicates that about four per cent of those BMET's employed by hospitals, and five per cent of those BMET's employed by companies leave the field. Hence the number of BMET's to be prepared annually is given by the following relationship:

$$\text{Number to be prepared} = 1.04[N_{h,t}-N_{h,t-1}] + 1.05[N_{c,t}-N_{h,t-1}]$$

Subscript h = hospitals, c = companies

Using our "most likely" estimates the number of BMET's to be prepared should increase from about 1300 per year in 1971 to about 1900 per year in 1975.

APPENDIX P. LIST OF PARTICIPANTS

APPENDIX P

LIST OF PARTICIPANTS IN SURVEY

California

St. Vincent's Hospital, Los Angeles
Good Samaritan Hospital, Los Angeles
Queen of Angels Hospital , Los Angeles
White Memorial Medical Center, Los Angeles
Childrens Hospital of Los Angeles, Los Angeles
Veterans Administration Hospital, Los Angeles
Kaiser Foundation Hospital, Los Angeles
Los Angeles County-USC Medical Center, Los Angeles
USC Shock Research Unit, Los Angeles
Dallons Instruments, El Segundo
Medi-Call Service, Los Angeles
G. E. - Service Division, Los Angeles
Picker X-Ray, Annaheim
Dundas Anesthesia, Los Angeles
Bendix Commercial Service Corp., Burbank
Instraservice, Los Angeles
Hewlett-Packard/Sanborn, North Hollywood
Burdick, Los Angeles
University Hospital of San Diego, San Diego
Veterans Administration Hospital, Palo Alto
Mills Memorial Hospital, San Mateo
San Francisco General Hospital, San Francisco
U. S. Public Health Service Hospital, San Francisco
Children's Hospital of San Francisco, San Francisco
St. Luke's Hospital, San Francisco
Mt. Zion Hospital and Medical Center, Neurolosurgical Research Unit, San Francisco
Veterans Administration Hospital, San Francisco
Letterman General Hospital, San Francisco
Franklin Hospital, San Francisco
Stanford Medical Center, Engineering Department, Palo Alto
Stanford Medical Center, Anesthesia Department, Palo Alto
University of California Medical Center, Cardiovascular Research Center, San Francisco

University of California Medical Center,
Department of Physiology, San Francisco
University of California Medical Center,
R & D Lab, San Francisco
Aldi Electronics Inc., San Francisco
Beckman Instruments, Palo Alto
Hewlett Pakcard, Mountain View
Corbin-Farnsworth, Div. of Smith Kline
Instruments, Service Division, Palo Alto
Varian Company, Palo Alto
Gentec Hospital Supply Co., South San Francisco

Colorado

Veterans Administration Hospital, Denver
Children's Hospital, Denver
St. Joseph's Hospital, Denver
General Rose Memorial Hospital, Denver
Rocky Mountain Osteopathic Hospital, Denver
U.S. Army Med. Opt. and Maint. Act.
Fitzsimons General Hospital, Denver
Fitzsimons General Hospital, Denver
Colorado General Hospital, Colorado University
Medical Center, Denver
Cobe Laboratories, Inc., Denver
Hewlett-Packard, Sales Division, Denver
Rocky Mountain Surgical, Denver
Technical Equipment Co., Denver
Muckle Equipment, Denver
Applied Technical Products, Denver
George Berberts and Sons, Denver
Johnnie Walker Medical Electronics, Inc., Denver

Washington, D. C.

Veterans Administration Hospital, Washington, D. C.
Providence Hospital, Washington, D. C.
Washington Hospital Center, Washington, D. C.
Walter Reed Army Medical Center, Washington, D. C.
Georgetown University Hospital, Washington, D. C.
American Hospital Supply, Scientific Products Div.,
Washington, D. C.
National Institutes of Health, Bethesda, Maryland
National Naval Medical Center, Bethesda, Maryland
Picker X-Ray Corp., Beltsville, Maryland
Hewlett-Packard, Rockville, Maryland

Florida

Baptist Hospital of Miami, Miami
Mount Sinai Hospital, Miami
Veterans Administration Hospital, Miami
Jackson Memorial Hospital, Miami
Miami Heart Institute, Miami Beach
American Hospital Supply, Scientific Products Div., Miami
Picker Medical Products, Hialeah
Hewlett-Packard, Ft. Lauderdale

Georgia

DeKalb County General Hospital, Decatur
Veterans Administration Hospital, Atlanta
St. Joseph's Infirmary, Atlanta
National Communicable Disease Center, Atlanta
Emory University Medical School, Atlanta
Cambridge Instrument Co., Inc., Atlanta
Scientific Products Division - American Hospital Supply Corp., Chamblee
Technicon, Inc., Atlanta
Curtin Scientific Company, Atlanta

Indiana

Community Hospital, Indianapolis
Methodist Hospital, Indianapolis
Winona Memorial Hospital, Indianapolis
Marion County General, Indianapolis
Indiana University Medical Center, Indianapolis
Akron Surgical Co., Indianapolis
Seller Instruments, Indianapolis
Curtis & French Co., Indianapolis

Illinois

Louis A. Weiss Memorial Hospital, Chicago
Presbyterian-St. Luke's, Chicago
Children's Memorial Hospital, Chicago
University of Illinois Hospital, Chicago
Medical Electronics, Chicago
Bendix, Chicago
Cambridge Instrument Co., Oak Park

Louisiana

Charity Hospital of New Orleans, New Orleans
LSU Medical School, New Orleans
Tulane University School of Medicine, Department of Medicine, New Orleans
Tulane University School of Medicine, Department of Psychiatry, New Orleans
Technical Associates of New Orleans, Inc., Metairie
G. E. Medical Systems, New Orleans
Picker Medical (Subdivision of Picker Corp.), New Orleans
Hewlett-Packard, Kenner
Caltronics, Inc., Metairie
Medical Devices, Inc., Kenner
Control Fabrication and Service Corp., New Orleans

Maryland

Baltimore City Hospital, Baltimore
Childrens Hospital, Baltimore
Sinai Hospital, Baltimore
University of Maryland Hospital, Baltimore
Hewlett-Packard Corp., Woodlawn, Baltimore
Bendix Commercial Service Corp., Columbia
Murray Baumgartner, Baltimore

Massachusetts

Children's Hospital, Boston
West Roxbury Veterans Administration Hospital, West Roxbury
Beth Israel Hospital, Boston
Massachusetts General Hospital, Boston
New England Deaconess Hospital, Boston
Faulkner Hospital, Boston
Kennedy Memorial Hospital for Children, Brighton
University Hospital, Boston University Medical Center, Boston
New England Medical Center, Boston
Hewlett-Packard, Medical Electronics Division, Waltham
Alpha Medical, Inc., Boston

Michigan

Schoolcraft College, Livonia

Hutzel Hospital, Detroit
St. John Hospital, Detroit
Henry Ford Hospital, Detroit
Mount Carmel Hospital, Detroit
Children's Hospital of Michigan, Detroit
Lafayette Clinic, Detroit
Picker X-Ray, Detroit
Detroit X-Ray, Detroit
G. A. Ingram, Detroit
Evan-Sharrat, Detroit
Electro-Medical Co., Detroit

Minnesota

Northwestern Hospital of Minneapolis, Minneapolis
Mt. Sinai Hospital, Minneapolis
Hennipen County General Hospital, Minneapolis
Lutheran Deaconess Hospital, Minneapolis
St. Mary's Hospital, Minneapolis
Veterans Administration Hospital, Minneapolis
St. Paul-Ramsey Hospital, St. Paul
Charles T. Miller Hospital, St. Paul
St. Joseph's Hospital, St. Paul
University of Minnesota Hospital, Minneapolis
Harold Medical Equipment Service, St. Paul
Joseph Dahl Surgical Co., Minneapolis
Universal Hospital Services, Minneapolis
Minnesota Medical Research Foundation, Minneapolis
Physicians and Hospitals Supply Company, Minneapolis

Missouri

St. Mary's Hospital, Kansas City
St. Luke's Hospital, Kansas City
Menorah Medical Center, Kansas City
Veterans Administration Hospital, Kansas City
University of Kansas Medical Center, Biophysics
Lab, Kansas City, Kansas
University of Kansas Medical Center,
Kansas City, Kansas
Research Hospital and Medical Center, Kansas City
Cambridge Instrument, Kansas City
Puritan-Bennett Corporation, Kansas City
Hewlett-Packard, Kansas City
K. C. Calibration and Repair, Kansas City
Barnes Hospital, St. Louis
St. Luke's Hospital, St. Louis
St. Mary's Hospital, Richmond Heights

Veterans Administration Hospital, St. Louis
St. John's Mercy Hospital, St. Louis
St. Louis University Hospital, St. Louis
Lutheran Hospital, St. Louis
St. Anthony's Hospital of St. Louis
De Paul Hospital, St. Louis
Electrodyne, Hazelwood
Sherwood Medical Industries, Inc., St. Louis
Picker X-Ray, St. Louis
ABC Medical Services, Inc., Overland
Hewlett-Packard, St. Louis
Gentec Hospital Supply, St. Louis
Instrumentation Lab., St. Louis

New Jersey

Jewish Hospital and Rehabilitation Center, Jersey City
Beth Israel Hospital, Newark
St. Barnabas Hospital, Livingston
Cherry Hill Hospital, Cherry Hill
Jersey City Medical Center, Jersey City
Sieners Corporation, Union

New York

New York Medical College Hospital, New York City
Montefiore Hospital and Medical Center, Bronx
Veterans Administration Hospital, Bronx
Mt. Sinai Hospital, Klingenstein Clinical Center, New York City
Morrisaria City Hospital, Bronx
Hebrew Hospital for the Chronic Sick, Bronx
New York University Hospital, New York City

Ohio

Baby's and Children's Hospital, Cleveland
Lutheran Hospital, Cleveland
Matheson Scientific, Cleveland
Harris Calorific Company, Cleveland
Brush Instruments, Division of Clevite Corp., Cleveland
E. G. Baldwin and Associates, Cleveland
Hewlett-Packard, Midwest Sales Region, Westlake
Schuemann-Jones Company, Cleveland
H. P. Gardner Repair Company, Cleveland

Pennsylvania

Albert Einstein Medical Center, Northern Division, Philadelphia
U. S. Naval Hospital, Philadelphia
Institute of Pennsylvania Hospital, Philadelphia
Temple University Health & Science Center, Philadelphia
Hahneman Medical College, Philadelphia
Thomas Jefferson University Hospital, Philadelphia
Bockus Research Institute, Philadelphia
Air-Shields, Inc. Hatboro
Medesco, Philadelphia
Smith, Kline & French Laboratories, Philadelphia
Children's Hospital of Pittsburgh
Shadyside Hospital, Pittsburgh
Suburban General Hospital, Pittsburgh
Alleghany General Hospital, Pittsburgh
Veterans Administration Hospital, Neuropsychiatric, Pittsburgh
Veterans Administration Hospital, Pittsburgh
Presbyterian University Hospital, Pittsburgh
Fisher Scientific Co., Pittsburgh
Hewlett-Packard Co., Monroeville
Impac Instrument Service, Pittsburgh

Texas

Methodist Hospital, Dallas
Children's Medical Center, Dallas
U. S. Air Force Hospital, Ft. Worth
Baylor University Medical Center, Dallas
University of Texas (SW) Medical School, Biomedical Engineering Lab, Dallas
Terrell Technical Division, Terrell Supply Co., Ft. Worth
Dallas Surgical Supply Co., Dallas
Honeywell Corporation, Dallas
Ben Taub Hospital, Houston
University of Texas, Houston
Texas Children's Hospital, Houston
Veterans Administration Hospital, Houston
Cardiovascular Research Center, Houston
Baylor College of Medicine and Research, Houston
Baylor College of Medicine, Experimental Surgery Department, Houston
Texas Institute for Rehabilitation and Research, Houston
Texas Heart Institute, Houston
Medirent, Houston
Beckman Instrument Co., Houston

Narco Bio-Systems, Houston
W. A. Kyle Co., Houston
Hewlett-Packard Corp., Houston

Washington

Providence Hospital, Seattle
Burien General Hospital, Seattle
Veterans Administration Hospital, Seattle
University of Washington, Seattle
Madigan General Hospital, Tacoma
Physio-Control, Seattle
Van Waters & Rogers, Inc., Medical X-Ray Department, Seattle
Seattle Surgical Repair, Seattle
Ohio Medical Products, Seattle
Profex-Ray, Seattle

Wisconsin

Veterans Administration Hospital, Milwaukee
Lutheran Hospital, Milwaukee
West Allis Memorial Hospital, Milwaukee
St. Francis Hospital, Milwaukee
St. Luke's Hospital, Milwaukee
Mt. Sinai Hospital, Milwaukee
Evangelical Deaconess, Milwaukee
Milwaukee County General Hospital, Milwaukee
Elm Brook Hospital, Milwaukee
Pengelly X-Ray Corporation, Milwaukee
General Electric Corporation, W. Milwaukee

APPENDIX Q. BIBLIOGRAPHY

APPENDIX Q

BIBLIOGRAPHY ON SAFETY AND BIOMEDICAL EQUIPMENT TECHNOLOGY

Articles on Safety

Many articles have been written concerning electrical equipment and safety in hospitals. The three bibliographies listed below contain among them a complete listing of all articles through 1969:

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Texas State Technical Institute, Waco, 1970.

Williams, Walter E., "The Preventive Maintenance Hurdle," Hospitals, J.A.H.A., January 16, 1970.

* The Naval Medical Research Institute includes over 1000 listings under the following headings:

Electrical Impedances
Physiological Thresholds to Electric Current
Pathophysiology of Electric Shock
Reported Sequelae of Electric Shock
Protective Technical Considerations
Peripherally Related Biological References
Review Articles

APPENDIX R. QUESTIONNAIRE

APPENDIX R

QUESTIONNAIRE

Data - by Company and Hospital

NOTE: Percentages included in the data on this questionnaire are based on the total number of responses (N) to the given question. For purposes of analysis in the body of the report, these figures were often recomputed on the basis of the total number of interviews.

BIOMEDICAL EQUIPMENT TECHNICIAN

INTERVIEW SCHEDULE

Interview Number_____

Interviewer_____

Name of Hospital/Company_____

Address_____

Type of Hospital:

Teaching	120
Research	111
General	136
Speciality	30
Research Institute	6
TOTAL INTERVIEWS	179

Type of Company:

Manufacturer	35
Supply House	52
Contract Maintenance	12
	99

Number of Beds_____
Annual Budget_____

Name of Respondent_____

Title_____

Relation to BMET's:

BMET	80
Company Supervisor (inc. service & sales managers, department heads)	85
Hospital Supervisor (inc. dept. heads, assistant administrators, 3 MD's)	39
Engineers	73
	278

Hospital/Company has a BMET training program? Hosp. 11% Co. 34%
Name of director or other knowledgeable person:_____

Interviewed? Yes___ No___

Suggested contacts in area: (names of other hospitals with BMET's, manufacturers, contract maintenance companies and supply houses frequently used by hospitals)

_____

_____

NOTE TO INTERVIEWER: Please go over the following definitions with your respondent before commencing the questionnaire. This will clarify what our survey is about as well as avoiding vagueness and misunderstanding.

Bio-Medical Equipment: the more complex kinds of medical equipment found in a hospital or research institute such as EKG machines, blood-gas analyzers, artificial kidneys, defibrillators, etc.

Bio-Medical Equipment Technician: (BMET - medical equipment repairman, field service repairmen) a technician who is responsible for helping in the maintenance and/or repair of the hospital's medical equipment.

Minor repair: a repair which would most likely take less than an hour and involves simple part replacements or corrections such as soldering a frayed wire, replacing a fuse, fixing the ON-OFF switch, adjusting the pilot light. This kind of repair would rarely require opening the cases (cabinets) of the equipment.

Major repair: a repair which calls for opening the casing of the equipment, skilled diagnosis and troubleshooting, most likely involving the inherent dangers of dealing with electrical systems such as replacing a transistor, replacing an optical detector, etc.

(HOSPITALS ONLY)

Individual hospitals have a variety of ways in which needed repairs on medical equipment are handled. We are interested in knowing what the different chains of events are when particular pieces of equipment in your hospital need repair. Please select the 2 or 3 pieces of equipment which best represent the different ways in which repair is accomplished. For each piece of equipment please number the chain of events as they usually occur.

Give Name of Equipment and Operator

EVENTS	Example: Portable X-ray - X-ray tech	#1	#2	#3
MACHINE BREAKS DOWN	1			
OPERATOR TRIES TO REPAIR IT	2			
OTHER HOSP. STAFF IN DEPT TRY TO FIX IT				
CALL PURCHASING	3			
PURCHASING CALLS MANU.	4			
PURCHASING CALLS CONTRACT MAIN. OR SUPPLIER				
PURCHASING CALLS IN-HOUSE BMET				
CALL IN MANU. TO PERFORM REPAIR				
CALL IN CONTRACT MAIN. CO. OR SUPPLIER TO PERFORM REPAIR				
EQUIPMENT REPAIRED IN DEPT.				
EQUIPMENT REPAIRED IN HOSP. REPAIR SHOP				
EQUIPMENT SENT OUT OF HOSP. FOR REPAIR	5			
PURCHASING ORDERS NEEDED PARTS				
BMET ORDERS NEEDED PARTS				
DEPT. STAFF RECORDS REPAIRS	6			
PURCHASING RECORDS REPAIRS				
BMET RECORDS REPAIR				
OTHER (specify)				

NOTE TO INTERVIEWER: If chain of events cannot be categorized as above, please elaborate here.

We are interested in knowing what types of bio-medical equipment technicians you have in your department. First of all, how many BMET's do you have?_____

Do they all perform basically the same tasks on the same kinds of equipment, or do you have specialists either by tasks or by types of equipment they work on? Please give identifying title to the different types of technicians and fill in the information below:

	PERCENT OF BMET'S	
N =	240	352
	COMPANY	HOSPITAL
NOT SPECIALIZED BY TASKS OR BY EQUIPMENT	13%	34%
SPECIALIZED BY TASKS: Preventive maintenance	5	5
Calibration	4	4
Minor repairs	9	7
Major repairs/troubleshooting	5	3
Mod/Des/Building	4	4
SPECIALIZED BY EQUIPMENT: ICU-CCU Equipment	21	6
Lab Equipment	8	3
X-Ray, Nuclear Medicine Eq.	11	5
Computers	1	0
Inhalation Therapy Equipment	5	4
Operating Room Equipment	1	2
Other	5	5
SPECIALIZED BY COMPONENTS: Electronics	3	11
Mechanics	3	4
Other	3	5

We are interested in identifying <u>all</u> the places in your hospital/company where BMET-types are employed. Please list below the names of all the departments besides your own where BMET's are employed, giving the number and the name and title of their supervisor.

_____

NOTE TO INTERVIEWERS: It is desireable to interview supervisor or technician from each of the departments mentioned above. If this is not possible, please ascertain the following from respondent:

TASK	(Name of Department)		
Preventive main./calib.			
minor repairs			
major repairs/troubleshooting			
mod/des/bld.			
Other			

Does your technician have a set routine that he follows every day/week? (Example: 9-10 check up on monitoring equipment attached to patient, 10-12 open for repair work, etc.) Please elaborate.

Could you estimate what percentage of the 'average' BMET's time is spent on each of the following functions?

	CO.	HOSP.
Administrative	9%	6%
Operating	3	4
Preventive maintenance/calib.	18	18
Major repairs/troubleshooting medical equipment	50	36
Instructing others	7	6
Modifying/designing/building	5	11
In training (upgrading)	6	5
General Hospital maintenance (non-medical equipment)	2	14
N=	94	173

Are there other kinds of functions which the technician performs not listed here? If so, what are they?

In a typical week, when working on equipment, what percentage of his time does the technician spend on the following components of equipment?

	CO.	HOSP.		CO.	HOSP.
electronics	51%	47%	electro-mechanics	19%	15%
optics	4	2	electro-optics	3	3
mechanics	16	21	pneumatics	2	4
hydraulics	4	3	Other	1	5
N=	94	173			

COMMUNICATION

In the process of performing his tasks, the technician interacts with numerous people, in and out of the hospital. For each of the following categories, please indicate the frequency of the interaction by writing the appropriate number from this scale:

1 = daily
2 = weekly
3 = rarely
4 = never
5 = when needed

Func/Interact.	Other BMET's	MDs, Interns	Nursing Staff	Para-Medicals	Persons From Out Hosp.	
Performing service (such as setting up, moving, oper.)	2.5	2.2	2.5	2.4	3.0	CO.
	2.3	2.1	2.1	2.1	2.8	HOSP.
Instructing on set up/safety	3.0	2.8	2.9	2.9	3.2	CO.
	2.7	2.8	2.5	2.6	3.4	HOSP.
Instructing on operation/use	2.9	2.6	2.8	2.7	3.2	CO.
	2.7	2.7	2.4	2.6	3.4	HOSP.
Advising on purchasing equipment	3.5	2.8	3.2	3.1	3.4	CO.
	3.2	3.0	3.3	3.3	3.5	HOSP.
Receiving instruction on operation, safety, main.	2.9	3.6	3.7	3.6	3.1	CO.
	2.8	3.4	3.4	3.4	2.9	HOSP.
Non-work rel. interactions	2.5	2.9	3.1	2.9	2.7	CO.
	2.0	2.6	2.4	2.3	2.8	HOSP.
N=	78	159				

Is any of the instruction that the technician gives done on a formal basis (at planned seminars, clinics, etc.)?

	FORMAL	INFORMAL	N
CO.	39%	61%	83
HOSP.	30%	70%	164

We are interested in knowing whether or not your technician performs any of the following tasks, and if so, how often. Please use the following code:

0 = not done by BMET
1 = done once a month or less frequently
2 = done several times a month
3 = done at least once a week
4 = done at least once a day
5 = done when needed
6 = done by non-tech supervisor

	0		1		2		3		4		5		6		
	C	H	C	H	C	H	C	H	C	H	C	H	C	H	
Determine order in which repairs should be accom.	6	8	1	2	1	2	7	4	71	68	3	2	11	13	%
Plan & schedule own assignments for the day	12	8	0	0	1	1	9	4	61	72	1	1	16	14	%
Plan & schedule assigns for other technicians	42	46	2	2	1	1	5	4	19	25	1	0	24	21	%
Maintain a log of daily activities	18	27	0	4	1	0	3	2	74	64	0	1	3	2	%
Maintain an inventory of spare parts	20	19	4	16	8	5	19	13	34	32	2	7	12	7	%
Maintain files manufac's manuals, circuit files	14	10	7	11	6	13	14	13	41	37	3	4	14	12	%
Coordinate & schedule PM program for med. equip.	34	29	17	9	11	9	8	12	7	23	4	2	19	16	%
Estimate cost of repair for item of equipment	22	34	9	8	11	8	9	7	36	27	6	7	8	8	%
Estimate how long a given repair will take	12	21	12	7	9	9	13	13	44	38	4	7	4	5	%
Bill other departments for services	45	61	1	4	6	2	8	2	33	23	1	1	7	7	%
Order supplies, spare parts from manufacturer, supply houses, etc.	18	15	4	4	2	3	22	17	41	45	3	9	9	7	%
Be on call for service during non-working hours	12	24	10	4	3	2	7	4	62	59	3	6	2	1	%
Interview and help select prospective BMET's	36	39	16	22	0	1	3	2	6	5	8	10	32	22	%
Make rounds/hosp. to check on safe installation of equipment	31	24	28	21	8	4	10	10	16	36	7	1	1	4	%
Transport faulty equip. to repair shop	12	12	12	8	13	10	19	12	37	53	7	4	0	1	%
Work with blueprints, wiring diagrams	3	5	3	4	0	4	9	10	83	75	1	2	0	0	%
Repair non-med. equip.: elevators, air conds, etc.	88	48	4	10	2	3	2	6	2	30	1	3	0	1	%
At normal location, be able to tell if equipment is correctly connected to patient	20	24	3	9	7	7	16	14	51	45	3	1	0	1	%
Selling/"hand-holding"	19	88	17	4	2	0	7	2	43	4	12	4	0	0	%

N = 90 165

NOTE: The equipment list below is by no means exhaustive. We have tried to develop a list which is representative of the different departments in a hospital as well as the different levels of complexity of medical equipment.

TYPE OF EQUIPMENT	# Co.	# Hos.	% Respondents: Do your technicians ever work with this type of equipment? YES C	YES H	NO, other hospital staff do C	NO, other hospital staff do H	NO, outside help does (& don't know C	NO, outside help does (& don't know H
LAB EQUIPMENT: CLINICAL & RESEARCH								
blood-gas analyzer	30	170	90	61	3	12	6	28
autoanalyzer	19	169	84	50	5	12	10	38
blood cell counter	33	170	88	45	3	13	9	42
refrigerated centrifuge	28	162	86	56	4	17	11	26
spectrophotometer	44	174	89	53	2	11	9	36
flamephotometer	32	173	88	51	3	11	9	37
stills	28	170	86	49	4	25	10	25
gas-chromatographs	33	161	88	36	3	13	9	50
mass spectrometers	18	158	89	25	6	15	5	60
pH meter (or titrator)	36	173	92	55	5	10	3	35
balance: precision (mech.)	24	169	92	36	4	17	4	47
balance: electronic	24	161	92	37	4	12	4	51
microtomes	29	169	90	35	3	17	7	48
microscopes	28	173	86	46	4	14	10	40
INTENSIVE CARE EQUIPMENT								
cardiac monitor	70	173	97	77	2	8	1	15
pacemaker (external)	60	171	93	67	2	9	5	23
EKG	74	176	99	80	1	6	0	14
defibrillator	66	173	95	76	2	6	3	18
alarm system	68	171	96	75	1	10	3	15
OPERATING ROOM EQUIPMENT								
respirator (ex. Bird)	38	171	92	48	3	25	5	27
electrosugical cauterizer	36	172	97	66	0	10	3	23
anesthesia apparatus	22	167	82	39	5	25	13	37
surgical pumps	34	173	97	57	3	19	0	25
heart-lung machine	12	155	83	41	0	20	17	39
X-RAY/NUCLEAR MEDICINE EQUIP.								
X-ray equipment	26	172	84	38	8	15	8	48
scintillation counter	26	171	85	37	12	13	3	50
radiation monitors	22	170	86	38	9	15	5	46
scanner	18	170	78	37	17	14	5	49
OTHER EQUIPMENT								
prosthetic devices	12	164	58	15	17	31	25	54
analog/digital computers	35	162	94	25	0	13	6	61
refrigerators	16	173	81	33	6	50	13	17
dental equipment	17	143	88	36	0	27	12	37
air conditioners	4	173	50	27	0	57	50	16
sterilizers	31	175	94	53	3	26	3	20
dialysis systems	12	156	75	37	0	19	25	43
incubator: infant	31	149	90	58	3	27	7	15

We hope that you will add to the list any pieces of equipment which you feel will help to make the list more representative of the kinds of equipment with which the bio-medical equipment technician might work.

Do your technicians perform preventive main./ calibration?								Does technician install equipment for operation/use?		% Yes Mentioned What kinds of repair to this equipment are beyond your technician's capabilities? (please specify)		% Yes Mentioned What kinds of repairs are carried out by your technician on this item of equipment? (please specify)			
YES						NO		YES				MAJOR		MINOR	
PM		CAL.		BOTH											
C	H	C	H	C	H	C	H	Co.	Hosp.	Co.	Hosp.	Co.	Hosp.	Co.	Hosp.
0	8	20	8	73	31	7	52	77	29	33	71	77	45	80	52
0	7	16	7	58	24	26	61	50	25	39	68	74	40	67	42
0	4	12	8	64	23	24	65	59	21	36	73	76	34	76	37
0	7	14	6	68	30	18	56	64	33	39	64	79	46	71	50
2	2	14	7	66	30	18	60	66	29	35	68	84	42	79	47
0	3	16	8	65	27	19	62	59	28	38	72	81	41	75	44
4	6	11	5	50	27	35	59	50	27	43	59	82	42	81	45
3	2	12	6	67	18	18	72	63	20	33	79	79	30	84	30
0	2	11	3	72	14	17	80	53	14	24	84	78	18	76	18
0	3	17	10	74	28	9	56	69	31	30	64	85	44	79	46
0	2	13	8	75	19	12	70	63	20	33	73	79	28	75	29
0	2	8	7	75	17	17	73	63	21	38	74	75	30	71	30
3	5	17	4	59	17	21	72	62	19	34	75	83	28	79	29
7	6	7	5	61	20	25	69	64	21	57	77	79	30	68	38
0	3	11	9	80	49	9	37	83	46	24	58	89	60	82	66
2	4	12	8	72	40	15	46	78	37	22	59	88	52	82	56
1	5	12	9	80	51	7	33	84	44	23	52	92	64	89	67
3	8	8	9	76	44	13	36	79	42	25	56	88	58	82	64
1	7	6	8	83	46	10	38	79	46	22	49	84	60	82	64
0	5	11	4	74	29	15	62	69	27	39	63	76	40	79	44
8	9	11	8	67	30	14	51	67	31	25	60	83	52	83	55
5	4	9	4	59	19	27	72	59	22	50	74	68	29	73	34
3	8	9	6	71	31	17	54	65	31	29	55	85	47	79	49
0	7	17	3	67	21	16	68	58	21	33	73	58	31	58	33
4	3	8	3	69	23	19	67	77	19	58	80	85	31	81	33
0	2	8	7	73	15	19	74	65	19	27	80	81	27	73	29
0	2	9	7	68	17	23	70	59	18	27	78	82	31	82	32
0	2	6	4	72	19	22	71	50	21	28	78	68	29	68	32
0	0	8	2	42	6	50	90	42	9	33	87	50	12	50	12
6	1	6	3	77	10	11	83	74	10	11	84	91	19	88	20
13	2	6	2	50	20	31	74	44	23	25	76	75	28	69	30
6	3	6	2	59	19	29	75	59	24	24	71	71	28	65	32
25	2	0	2	25	17	50	77	0	21	50	76	50	21	25	25
3	5	16	6	61	29	20	58	58	35	26	61	84	46	77	49
0	3	8	4	58	17	34	75	50	18	33	79	58	26	67	30
6	4	10	7	68	36	16	52	58	32	16	55	87	47	77	52

What are the job entry performance levels that you expect from the technicians you hire as they relate to the following pieces of equipment?

TYPE OF EQUIPMENT	# Co.	# Hosp.	I do not expect tech. to be familiar with this equip. C	H	Has a knowledge of physio./ chemical principles on which input sig. to equip. is gen. C	H	Has a knowledge of manner in which equip. transforms input sig. to an output sig. C	H
LAB EQUIP.:CLIN. & RESEARCH								
blood-gas analyzer	31	171	54	69	13	15	35	25
autoanalyzer	19	169	58	71	16	13	42	23
blood cell counter	35	166	63	76	14	11	31	19
refrigerated centrifuge	30	165	57	65	23	14	33	25
spectrophotometer	45	173	60	72	16	14	36	23
flamephotometer	33	172	58	72	15	13	39	22
stills	31	171	65	70	16	11	29	20
gas-chromatographs	32	159	59	78	9	11	34	18
mass spectrometers	21	155	52	81	14	10	43	17
pH meter (or titrator)	36	172	56	70	14	17	36	24
balance:precision(mech.)	28	168	50	77	14	8	39	17
balance:electronic	26	161	62	76	12	11	35	19
microtomes	34	169	56	80	18	8	26	14
microscopes	35	172	63	78	14	10	23	16
INTENSIVE CARE UNIT EQUIP.								
cardiac monitor	73	172	62	56	12	23	27	37
pacemaker (external)	61	172	61	58	15	20	30	34
EKG	73	175	58	59	14	19	32	35
defibrillator	67	171	61	59	13	20	28	35
alarm system	66	170	56	56	15	20	33	35
OPERATING ROOM EQUIP.								
respirator(ex. Bird)	39	168	62	67	15	13	26	21
electrosurgical cauterizer	35	172	57	66	23	13	29	25
anesthesia apparatus	24	164	54	73	13	11	21	19
surgical pumps	37	171	51	66	24	14	30	26
heart-lung machine	15	153	53	76	27	13	44	17
X-RAY/NUCLEAR MED. EQUIP.								
X-ray equipment	25	169	72	72	0	14	20	24
scintillation counter	25	168	68	77	8	13	32	21
radiation monitors	22	168	64	77	5	11	27	20
scanner	20	169	75	79	5	12	20	19
OTHER EQUIPMENT								
prosthetic devices	14	159	64	88	14	4	14	8
analog/digital computers	33	160	55	83	12	8	36	15
refrigerators	19	171	58	74	11	9	5	16
dental equipment	17	145	53	76	18	10	35	18
air conditioners	8	168	63	76	-	5	25	14
sterilizers	34	173	65	64	18	13	26	25
dialysis systems	14	157	57	78	7	10	29	17
incubator:infant	33	154	61	66	12	10	30	23
GENERAL	98	175	64	55	13	25	28	44

MUST KNOW BASIC ELECTRONICS CO. (96) 77% HOSP. (170) 75%

Demonstrates ability to operate the equipment		Demonstrates ability to locate and diagnose faults and repair equip.		Are on-the-job training programs for this type							
				1 In-House		2 Manu.		3 Self-Train		0 Spec. Tech	
C	H	C	H	C	H	C	H	C	H	C	H
19	21	35	22	26	25	26	6	3	9	7	36
26	18	36	21	26	24	26	7	11	7	11	45
20	16	29	18	29	23	26	6	6	8	9	46
27	21	33	27	20	27	30	4	3	13	10	37
20	18	31	22	31	26	27	4	4	9	7	42
18	19	33	22	30	25	24	4	3	8	9	44
19	18	35	22	35	23	19	4	--	9	13	47
13	14	31	17	19	16	44	5	3	5	9	58
29	14	43	15	19	13	29	4	10	3	10	66
19	20	36	22	31	29	28	4	6	9	6	40
32	15	36	16	29	16	25	2	4	8	7	58
23	18	31	19	23	18	35	4	8	8	8	55
29	14	38	15	29	17	20	2	3	5	11	61
29	15	26	17	26	26	23	2	6	7	14	51
19	28	32	35	26	31	45	9	3	10	4	22
20	25	36	31	28	30	41	7	2	11	8	29
21	26	34	33	29	34	44	7	4	10	1	21
19	24	34	32	27	32	40	7	4	12	6	23
21	26	39	34	27	34	44	7	2	10	5	21
21	20	31	25	26	23	28	4	5	10	10	44
22	19	36	27	36	31	14	5	6	11	8	33
25	18	33	20	13	21	25	5	4	7	21	53
22	21	39	27	42	29	13	5	8	11	6	39
20	17	31	20	13	21	13	5	7	4	33	53
12	21	16	24	21	15	33	4	--	8	17	55
12	16	19	18	15	17	27	3	4	7	23	57
14	17	18	17	27	16	23	3	5	7	14	58
10	15	20	17	15	17	20	2	5	6	25	57
21	7	21	9	14	10	7	2	7	3	36	77
21	11	33	13	12	11	48	3	6	4	6	69
16	15	32	20	21	15	11	1	11	12	26	58
29	11	29	15	29	17	18	2	6	9	18	58
13	14	25	18	--	13	--	2	25	10	50	63
18	20	26	25	32	20	18	4	6	12	12	41
14	12	36	15	14	16	14	4	7	5	36	58
21	20	34	25	34	27	19	2	9	13	13	38
23	34	35	44								

pe of equipment provided?

	4 No Tr.Nec.		5 Other		6 1 + 2		7 1 + 3		8 2 + 3		9 1,2,3	
	C	H	C	H	C	H	C	H	C	H	C	H
		3		2	32	10		3		2	3	4
		3		2	21	7		2		1	5	3
		3		2	29	7		2		1	3	3
		3		2	33	7		3		1	3	2
		4		2	29	7		3		1	2	3
		4		2	30	8		3		1	3	2
		4		3	29	7		2		1	3	1
		3		1	22	6		3		-	3	3
		3		1	29	5		3		-	5	3
		3		2	31	8		3		1	-	3
		4		2	32	4		2		1	4	2
		3		1	23	4		3		1	4	3
		2		2	34	2		3		2	3	2
		4		2	31	4		2		1	-	2
		3	1	2	18	14	1	2		4	1	4
		3	2	2	18	11	-	2		3	1	3
		4	-	2	21	12	-	2		4	1	3
		3	1	1	19	13	-	2		4	1	4
		4	2	2	18	14	2	1		4	2	4
		3		2	28	8		1		3	3	2
		4		2	33	7		2		2	3	2
		3		2	33	6		1		1	4	2
		2		2	28	8		3		1	3	1
		3		1	27	7		3		1	7	1
		5		2	21	4	4	1		2	4	2
		4		1	23	5	4	1		2	4	2
		3		1	23	6	5	1		2	5	2
		3		1	20	7	5	1		2	10	2
		3	7	1	29	2		1		1	-	1
		3	-	1	24	4		3		1	3	2
		3		1	26	4		1		2	5	2
		4		2	24	4		1		2	6	1
		3		1	25	4		1		2	-	2
		3		2	29	9		2		3	3	4
		3		2	29	7		1		1		3
		3		2	22	8		2		2	3	3

CAREER

Do you have different grades/levels of technicians?

CO.(87) 53%, HOSP.(171) 51%

If yes, are these equivalent to the types of technicians you outlined at the beginning of the questionnaire?

CO.(87) 29%, HOSP.(171) 33%

How many grades of technicians do you have?

CO.(47) 3.5, HOSP.(87) 2.8

Does one grade of technician supervise another grade?

	CO.	HOSP.
Yes, often	47%	53%
Yes, sometimes	27%	24%
No	26%	23%
N =	49	88

How does a technician move from one grade of technician to another?

	CO.	HOSP.
seniority	27%	29%
displayed ability(technical)	85%	80%
going to school	33%	37%
based on experience	48%	48%
Other (specify)	13%	13%
N =	48	87

How long does a technician usually stay at any one grade?

CO.(37) 2.4 years, HOSP.(53) 2.9 years

Do BMET's ever move from technician to engineer status?

CO.(79) 49%, HOSP.(159) 40%

If YES, how do they do this:

	CO.	HOSP.
seniority	10%	15%
displayed ability	74%	44%
going to school	67%	77%
based on experience	45%	36%
Other (specify)	12%	5%
N =	42	64

How long does a technician usually stay at the technician level before moving to engineer status?

CO.(30) 8.4 years, HOSP.(35) 6.7 years

MANPOWER

How many BMET's are presently employed in your department? (This information was ascertained on page 4)

How many BMET's are presently employed in your Hospital (Company)?

Is the number of BMET's currently employed in your hospital (company) sufficient for the hospital's (company's) current needs, in light of the present system of medical equipment repair and maintenance?

CO. 57%, HOSP. 42%

If NO, what constraints have prevented your hospital (company) from hiring more BMET's?

	CO.	HOSP.
lack of funds for salaries	26%	59%
lack of available trained technicians	54%	44%
lack of manpower to train technicians	11%	8%
lack of supervisors for technicians	3%	7%
Administrator not aware of the cost/benefits of maintaining and repairing equipment	8%	28%
Other (specify)	18%	17%
N =	39	109

What was the first year in which the hospital (company) employed a BMET?

CO. 1952, HOSP. 1959

For the following years, please answer these questions:

		66	67	68	69	70	71	72	75
How many BMET's did you(do you)expect to employ in:	Co(75)	3.4	4.1	6.3	7.4	8.5	10.3	12.0	15.6
	H(154)	2.1	2.4	2.7	3.1	3.8	3.7	4.2	5.6
How many BMET's left hospital employ in:	Co(74)	.2	.4	.5	.7	.2			
	H(145)	.2	.2	.4	.4	.1			
How many of those left the field of BME in:	Co(72)	.1	.2	.3	.5	1.4			
	H(140)	.1	.1	.2	.1	.0			

What do you think is the most important reason(s) which lead to their leaving the field?

	CO.	HOSP.
just wanted a change--of job,city,experience	9%	13%
lack of opportunity to advance in position	22%	15%
inadequate salary	21%	44%
lack of interest in work	13%	7%
lack of competence to perform tasks	43%	16%
interpersonal conflicts	14%	8%
military services	7%	3%
return to school	13%	15%
Other (specify)	23%	34%
don't know	2%	9%
N =	56	74

What factors do you feel will determine the growth in numbers of BMET's employed in your hospital (company) in the future?

	CO.	HOSP.
hospital acquiring more medical equipment	51%	70%
hospital reorganizing its present system of maintenance	13%	31%
more interest/emphasis on preventive maintenance and safety	35%	34%
training programs producing more BMET's	11%	19%
more funding available	19%	38%
company diversifying - selling a wider variety of equipment	49%	5%
company providing more service to hospitals	56%	2%
company increasing sales	76%	1%
Other (specify)	14%	23%
growth in number of BMET's not anticipated	2%	5%
N =	85	160

Of the BMET's your department has hired, approximately what percent had some BMET training before you hired them and thus needed minimal training on the job?

CO.(92) 21%, HOSP.(170) 39%

Where were they trained? Please give percentages (and, where possible, numbers) of BMET's and specifics about type of job, school, etc.

	Percent (and no.) of BMET's		
	Co.	Hosp.	Specify job, school, etc.
On another job: in a hospital	7%	13%	
On another job: not in a hospital	23	22	
In a BMET training program	2	8	
School	1	6	
Other: (specify)	14	26	
N =	40	90	

Therefore, 78%(Co.), 60%(Hosp.) of the BMET's who your department hired needed to be trained on the job.

What are the educational backgrounds of the BMET's you have hired? (Please give percentage and number where possible.)

	PERCENT OF BMET'S	
	CO.	HOSP.
Not a high school graduate	5%	5%
High School Graduate	29	29
Post-high school	66	66
N =	83	161

What areas were your BMET's working in before you hired them? (Please give percentage and number where possible.)

	PERCENT OF BMET'S	
	CO.	HOSP.
Bio-med equipment technician	15%	23%
Electronics	57	41
Mechanics	7	11
Optics	1	0
Electro-optics	1	1
Electro-mechanics	3	3
OTHER	16	21
N =	83	159

What is the average salary you pay a technician who has not completed his training?

CO. (72) $6-7,000/year HOSP. (131) $6-7,000/year

What is the average salary you pay a technician once he has completed his training?

CO. (75) $8-9,000/year HOSP. (147) $8-9,000/year

What is the maximum salary a person could expect at the highest BMET level in your hospital/company?

CO. (67) $10-11,000/year HOSP. (143) $9-10,000/year

What are the job qualifications for the position of BMET in your hospital/company?

	Electronics	Mechanics	Chem Phys etc.	Neat appear.	Personality	Comunic. Skls	Initiative	Education	Job Exp. Imp.	N
CO.	83%	36%	21%	24%	41%	39%	24%	57%	33%	90
HOSP.	74	37	26	8	31	15	20	56	40	169

TRAINING

How are your employees currently trained to be BMET's?

CO.	HOSP.	
90%	92%	1. Pick up skills on the job as needed; i.e. informal training.
46	31	2. Occasional planned in-house training session.
29	9	3. A formal in-house on-going program of training.
13	7	4. A formal on-going program of training with other hospitals, manufacturers, or educational institutes.
		5. By taking some courses at:
3	6	A. a local high school
11	11	B. a public technical institute (13-14 grades)
11	9	C. a private technical institute (13-14 grades)
6	10	D. a community college
3	19	E. a university or college
28	38	F. a non-educational institution (ex. manufacturer)
9	11	G OTHER (specify)_____
		6. By enrolling in a coordinated program at:
0	0	A. a local high school
0	1	B. a public technical institute
1	1	C. a private technical institute
1	2	D. a community college
2	1	E. a university or college
9	5	F. a non-educational institution (ex. manufacturer)
3	6	G. OTHER (specify)_____

90 161 = N

NOTE TO INTERVIEWER: If 3 and 4 are checked, find out who it is in hospital/company who knows about this program.

Name_____
Title_____
Arrange to talk to this person using TRAINING PROGRAM QUESTIONNAIRE.

Do you think that your hospital/company would consider establishing a collaborative BMET program with educational institutions and/or other hospitals and companies?

CO. (83) 59% HOSP. (154) 82% Why Not?_____

_____

Would your hospital/company hire the graduates of a collaborative 2-year BMET training program at your local community college or technical institute?

CO. (88) 90% HOSP. (158) 92% Why Not?_____

_____

If your hospital/company were establishing a collaborative educational program, please rank your preference for working with the following. (Indicate equal preference by using a given number more than once. 1 - first choice. Number only those you would actually work with.)

# FIRST CHOICES CO.	HOSP.	
5	17	High School (vocational)
4	6	High School (non-vocational)
28	44	Public technical institute (13-14 grades)
33	42	Private technical institute (13-14 grades)
19	52	Community College
18	42	University or college (4 years)
8	22	Other hospitals (please give names) _____ _____
4	14	Other manufacturers, supply houses, etc. (please give names) _____ _____
4	4	OTHER (please specify) _____ _____
14%	16%	No preference.
80	146	= N

If you were designing a BMET training program, assuming that you could only select 5 or 6 pieces of medical equipmwnt to treat intensively in the program, which items would they be?

_____

_____

_____

_____

_____

_____

(HOSPITALS ONLY)

SAFETY

Does your hospital have a safety code (or codes) concerning what kinds of equipment may be brought into the hospital and what kinds of equipment may be grouped together in a particular unit?

HOSP. (152) 68%

If YES, COULD WE HAVE A COPY? (Pick up at the end of interview)

Who sets the safety code? (state, hospital, M.D.s)

_____

Who checks to make sure safety standards are met?

Safety Inspector	36%
Safety Committee	28
Plant Engineer	29
BMET's	37
Other	35

N = 121

NOTE ANY ADDITIONAL COMMENTS HERE.

INTERVIEWER ONLY

Where in the hospital (geographically) is the home base of the BMET's located? (Describe atmosphere, setting, etc.)

What do the BMET's wear? (whites, suits, etc.) Does he have a beeper?

Is the interviewee a person who might be useful in reviewing and commenting on the rough draft of the report?

Did you have the sense that this hospital is ready to develop a full-scale (centralized or decentralized) BMET staff? (elaborate)

Please record any interesting comments made by the interviewee below.

APPENDIX S. CONTRIBUTORS

APPENDIX S

CONTRIBUTORS

PROJECT DIRECTOR: P. John Cadle

SURVEY DIRECTOR: Anne H. Cohn

RESEARCH ASSISTANTS: Hannah Gilman
Marge Stone

INTERVIEWERS: Jean Brewer
Martin Chalfie
Anne H. Cohn
Hannah Gilman
Roz Goren
Karen Kramer
Jean Mann
John Page
Jessica Simon
Marge Stone

IN-HOUSE CONSULTANTS: Roger Bull
Dean A. DeMarre

ADDITIONAL CONTRIBUTORS: Charles MacBrian
John Oxenham

SECRETARIAL STAFF: Pat Kent
Dorothy Magee

OUTSIDE READERS: (See Reader's Comments, Appendix D)

Paul L. Attwood
Methodist Hospital
Irving, Texas

Hal C. Becker
Professor of Biomedical
Engineering (Radiology)
Tulane University
School of Medicine
New Orleans, Louisiana

Robert Bevan
Product Service Manager
Medical Equipment Service
Department
Puritan-Bennett Corporation
Lenexa, Kansas

W. L. Bloom Manager
Manpower Development
General Electric
Milwaukee, Wisconsin

Allen Borkenhagen
West Allis Hospital
West Allis, Wisconsin

George W. Burton
Lutheran Deaconess Hospital
Minneapolis, Minnesota

Dr. Dean Crocker
Children's Hospital
Boston, Massachusetts

W. E. Dellegar, Program Head
Biomedical Technology
Grossmont College
El Cajon, California

Robert Dresser
Electro-Med Company
Detroit, Michigan

Hugh Flowers
Medical Technician
Hewlett-Packard
Kenner, Louisiana

Henry J. Kopchinski
Newark Beth Israel Medical
Center
Newark, New Jersey

E. B. Lanctot
St. Mary's Hospital
Minneapolis, Minnesota

Marvin Lough
University Hospitals of
Cleveland
Cleveland, Ohio

Rudolph A. Lucente
Clinical Instrument Service
Thomas Jefferson University
Hospital
Philadelphia, Pennsylvania

Robert D. Luchi
Bendix Commercial Service Corp.
Columbia, Maryland

John H. Maness
Xerox Center for Health
Care Research
Baylor College of Medicine
Texas Medical Center
Houston, Texas

Carlos Martin
Texas Heart Institute
Houston, Texas

Dave McKinney
Electronics Consultant
California Regional Medical
Programs - Area 1
San Francisco, California

S. M. Meyers, Chief,
Systems Maintenance Section
Department of Health,
Education and Welfare
Bethesda, Maryland

Carl J. Ogden
Madigan General Hospital
Tacoma, Washington

Robert C. Paul
Director of Engineering
Baylor University Medical
Center
Dallas Texas

Robert B. Spooner
IMPAC
Pittsburgh, Pennsylvania

P. E. Stanley
Purdue University
School of Aeronautics, Astronautica and Engineering Sciences
Lafayette, Indiana

Earl A. Sullwold
St. Paul Ramsey Hospital
St. Paul, Minnesota

Louis E. Tarnowski, Ph.D.
Department of Biological Sciences
Queensborough Community College
Bayside, New York

Gaylord M. Twite
V. A. Hospital
Minneapolis, Minnesota

Cliff Weiffenbach
National Service Repair Manager
Sherwood Medical Industries Inc.
St. Louis, Missouri